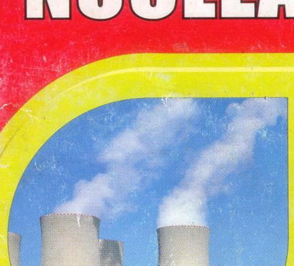
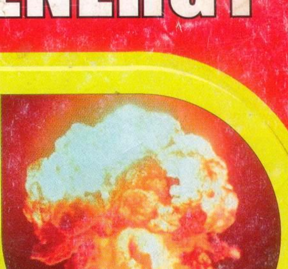
MANORAMA

TELL ME WHY

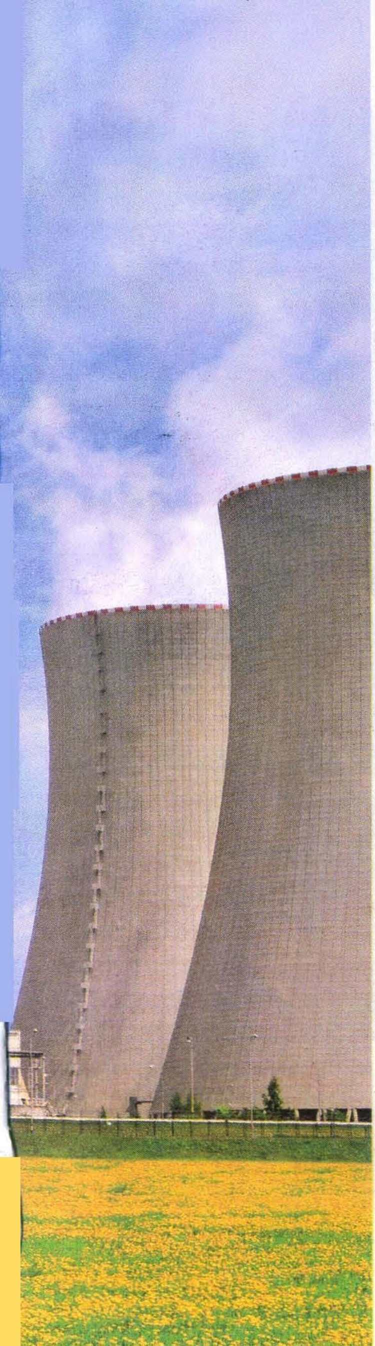
No:91

WONDERS OF NUCLEAR ENERGY





FUN-TO-READ HARD FACTS



MANORAMA
TELL ME WHY
April 2014 • Volume: 8 • No: 4

FROM THE HOUSE OF MAGIC POT, THE WEEK, MANORAMA YEARBOOK, VANITHA & THE MALAYALA MANORAMA DAILY

A BOON OR A BANE?

The need for new sources of energy is increasing day by day, because existing energy resources are getting rapidly used up. But, nothing to worry. Science has already identified an evergreen spring of power - nuclear energy. It's the largest source of energy that Man has ever found.

However, though nuclear energy has wide uses, it also has, sadly, the power to destroy everything. The world still remembers the bombs that devastated Hiroshima and Nagasaki. The disasters at nuclear power plants have also added to the fear of nuclear energy.

As the debate on its pros and cons rages on, Tell Me Why takes you to the wonder world of nuclear energy.

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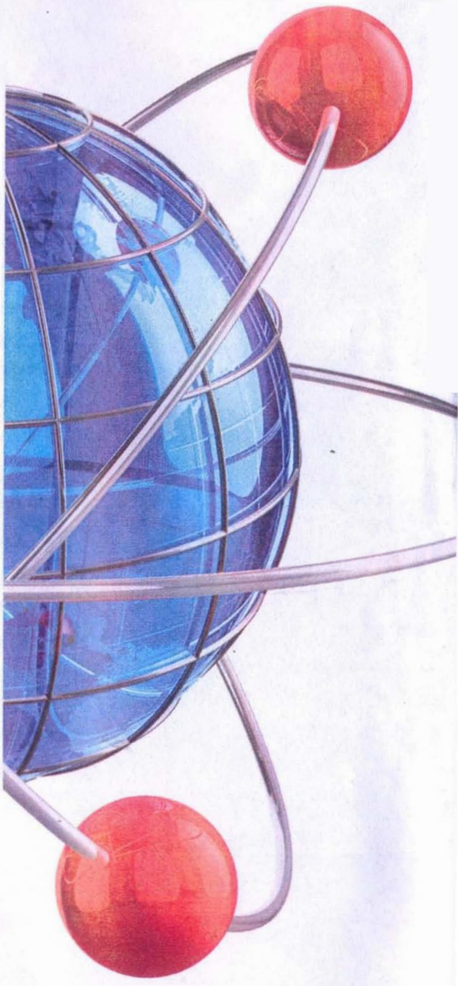
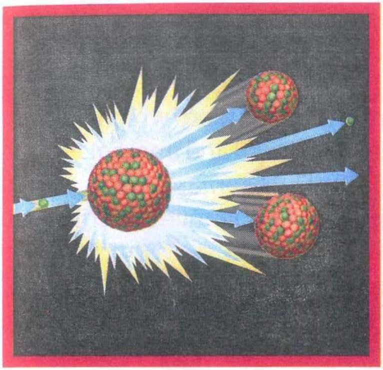
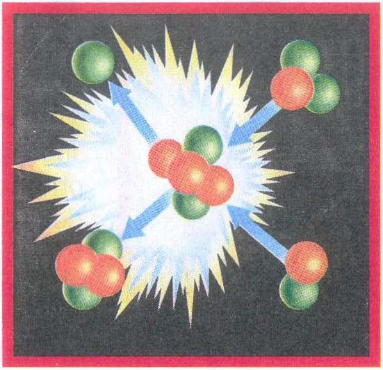
Mystery of the Atom



Tell Me Why



Nuclear Fission



Nuclear Fusion

What is nuclear energy?

Nuclear energy is the energy in the nucleus, or core of an atom. Atoms make up everything in the universe, and are held together with great force.

In a process called fission, atoms are broken apart, and energy is released. Atoms of uranium, a common element that can be mined from the Earth, are used in nuclear reactors.

In fission, a tiny particle called a neutron hits a uranium atom and the atom splits. This releases more neutrons, and generates a chain reaction. That reaction releases huge amounts of energy.

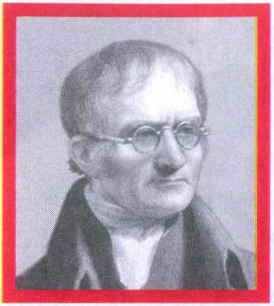
Nuclear energy is also produced when two atoms join to become a new atom. This process is called fusion.

Eco-Friendly Energy

Nuclear energy is very eco- friendly. It doesn't release any harmful gases into the atmosphere, and around 11 percent of the world's electricity is produced by nuclear energy.

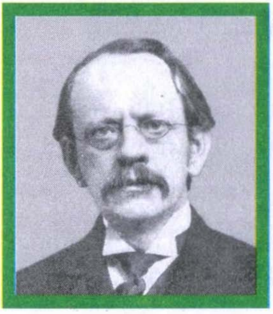
Why is the history of nuclear energy linked to the history of atom?

'Atom' is a Greek word which means 'indivisible,' and it was the ancient Greek philosopher Democritus who first defined atom as the smallest particle of matter.



John Dalton

However, it was only in the 19th century that John Dalton declared that elements are formed from certain combinations of atoms.

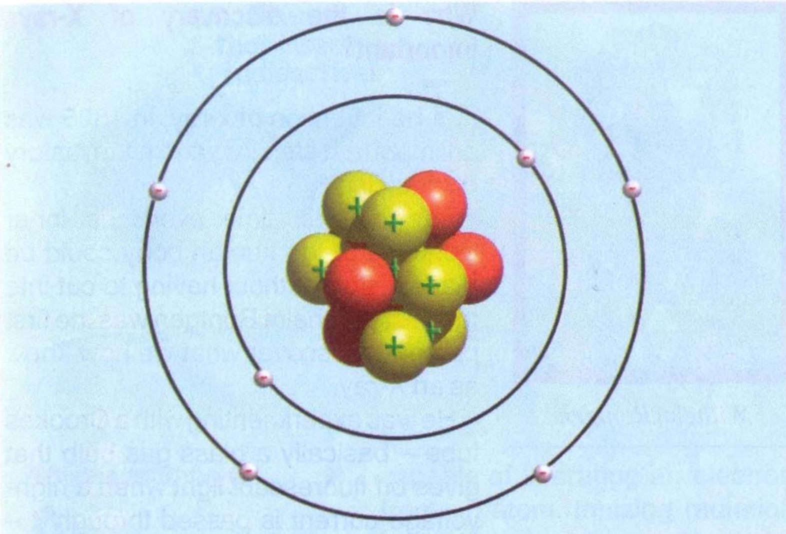


J.J. Thomson

The next step forward was when the elements were classified, and arranged in order. In 1897, J.J. Thomson announced the discovery of a negatively charged particle in an atom, which he called the electron. Further research by different scientists threw light on the nature and structure of atom- and it was this understanding of atom that paved the way to the development of nuclear energy.

Isotopes

Elements are defined by the number of protons in an atom's nucleus. In addition to protons, the atoms of every element -except hydrogen- also contain neutrons. When an element's atoms have different numbers of neutrons, they are said to be isotopes of that element.


Structure of an Atom

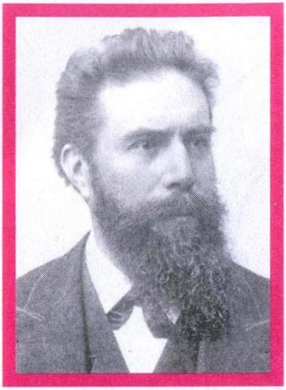
What is the structure of an atom?

It is important to get an idea of the structure of an atom to understand how nuclear energy is produced.

Contrary to what the ancient Greeks believed, an atom is not the smallest particle of matter. The outer part of an atom consists of a cloud- often called shell or orbit - of particles called electrons, while inside this 'cloud' is the inner core or the nucleus. The nucleus is again made up of particles called protons and neutrons.

There are even smaller particles moving around in atoms. These super-small particles can be found inside the protons and neutrons. Scientists have many names for those particles, but they are usually known as nucleons and quarks.

Protons are positively charged, while electrons are negatively charged, and neutrons have no charge at all.



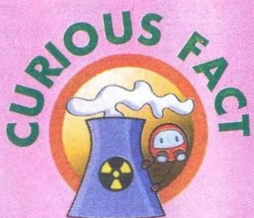
Wilhelm Rontgen

Why is the discovery of X-rays important?

The invention of x-ray, in 1895 was an important step forward in the history of medicine.

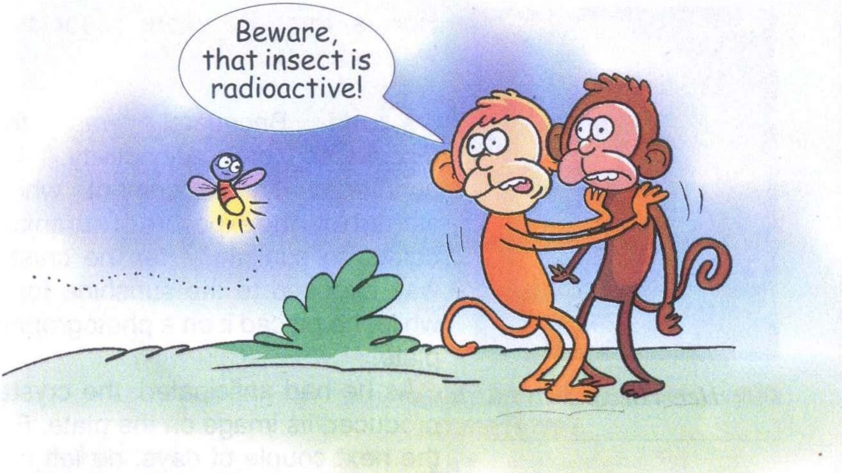
For the first time ever, the inner workings of the human body could be made visible without having to cut into the flesh. Wilhelm Rontgen was the first person to discover what we now know as an X-ray.

He was experimenting with a Crookes tube – basically a glass gas bulb that gives off fluorescent light when a high-voltage current is passed through it – when he noticed that the beam turned a screen, three metres away, into a greenish fluorescent colour, despite the tube being shielded by heavy black cardboard. Rontgen concluded, correctly, that he was dealing with a new kind of ray. Not knowing what kind of ray, he was dealing with exactly, he called it an X-ray.



Killer Radiation

Samuel Prescott used radiation to kill the bacteria in food in 1898 . He subjected various foodstuffs to gamma rays, and found that spoilage was greatly delayed.



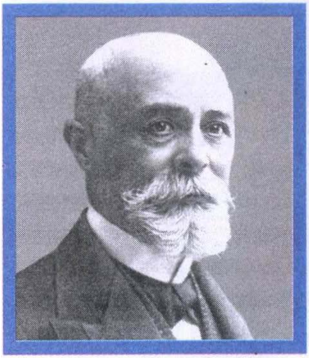
What is radiation?

All objects- including your body- give out some energy and heat. Energy that leaves an object in the form of waves is called radiation.

Sunlight and radio waves are some forms of radiation. Some types of radiation come from nature and can be found in soil, air and water.

In fact, there are two different types of radiation. They are called ionizing and non-ionizing radiation. Ionizing radiation is high energy radiation, which is capable of liberating an electron from an atom. Ionizing radiation is of different types that are named by letters of the Greek alphabet. The first letter is Alpha and this type of radiation is the weakest. The second letter is Beta, and this type of radiation is stronger, and can cause harm if you are not careful. The third letter is Gamma, and this type is the most powerful.

Non-ionizing radiation is relatively low-energy radiation. It doesn't have the energy to ionize atoms. Although considered less dangerous than ionizing radiation, overexposure to non-ionizing radiation can cause health problems.



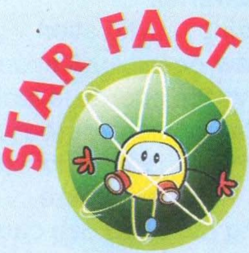
Henri Becquerel

How is Henri Becquerel associated with radioactivity?

Henri Becquerel was the discoverer of radioactivity. He conducted an experiment which started with the exposure of a uranium crystal to sunlight. After the crystal was exposed to the sunshine for a while, he placed it on a photographic plate.

As he had anticipated, the crystal produced its image on the plate. For the next couple of days, he left this sample of uranium in a closed drawer, along with the photographic plate. When he returned, he was surprised to find that the crystal had left a clear image on the photographic plate.

The result was astounding, because there had been no source of energy to produce the image! In short, he had discovered radioactivity!



Sievert

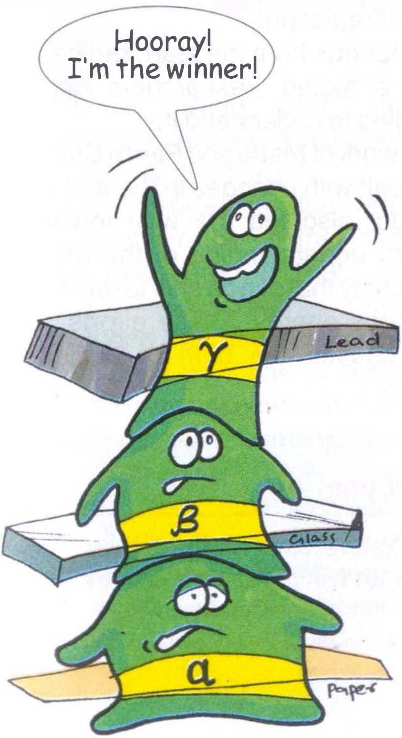
Most countries measure radiation dose using the metric system unit of Sievert. Figures are generally given in millisievert, or mSv, which is 1000^{th} of a Sievert.

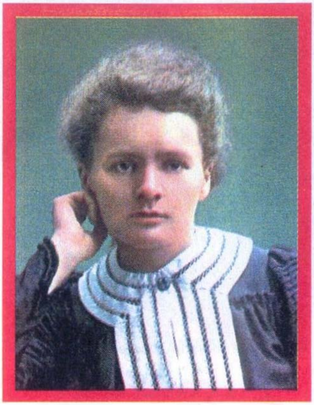
What are Alpha, Beta, and Gamma Rays?

When radiation of high enough energy strikes another atom it strips away an electron. The resulting positively charged atom is called an ion. Ionizing radiation is of three types- alpha particles, beta particles, and gamma rays.

Alpha particles are slow and heavy, and not very dangerous. Beta particles are electrons that move very quickly, and with a lot of energy, and more dangerous too.

Gamma rays are the most dangerous form of ionizing radiation. They have extremely high energy and can travel through most forms of matter because they have no mass.





Marie Curie

Why did the discovery of radioactivity lead to the birth of nuclear science?

It was Henri Becquerel who discovered radioactivity, quite by accident in 1896, and this triggered a lot of research in this field.

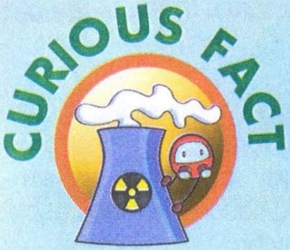
Many radioactive elements were discovered and in 1899, Ernest Rutherford discovered that uranium compounds produce three different kinds of radiation.

Mysterious from the start, radioactivity attracted researchers who struggled to understand it.

The work of Marie and Pierre Curie, that dealt with changes in the atomic nucleus, also led the way toward modern understanding of the atom as an entity that can be split to release enormous energy. These efforts, in time, caused the birth of nuclear science.

Nobel Curie

Marie Curie received another Nobel Prize in 1911, this time for Chemistry, for her work on the isolation of pure radium. She is the first person to win two Nobel Prizes.



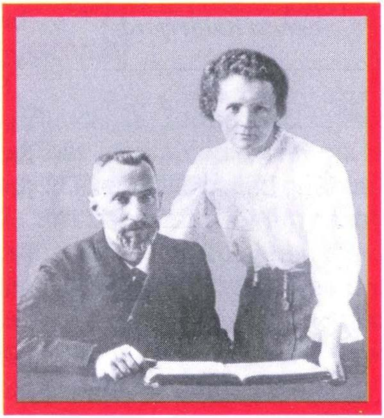
Gamma Rays

A French physicist and chemist by the name of Paul Villard discovered gamma rays in 1900. Villard realized that they were different from X-rays because they had much greater penetrating power.

Why are Pierre and Marie Curie legends in the field of radioactivity?

Marie Curie and her husband Pierre were pioneers in the study of radiation.

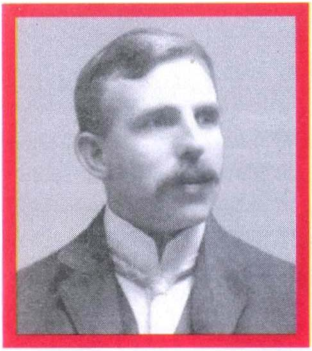
Marie decided to study the mysterious radiation that had been discovered in 1896, by Henri Becquerel. She concluded that, the substance pitchblende contains a small amount of an unknown element that was capable of spontaneous radiation.



Pierre and Marie Curie

Pierre Curie also joined his wife's work. In the course of their research, they discovered two new elements with the same characteristic, which they named polonium and radium. They were the first to use the term 'radioactivity' for this phenomenon of spontaneous radiation.

In 1903, Pierre and Marie Curie were awarded the Nobel Prize for Physics, along with Henri Becquerel, for their work.



Ernest Rutherford

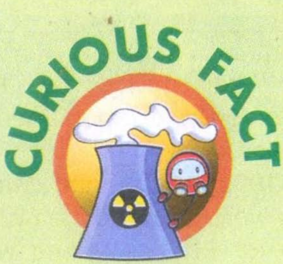
Why is Rutherford's atomic model of great importance in the study of the atom?

A British physicist, Ernest Rutherford, took giant steps forward in the study of atoms, when he named, and described many aspects of radioactivity.

Rutherford worked on radioactivity and coined the terms 'alpha' and 'beta' to describe the two different types of radiation.

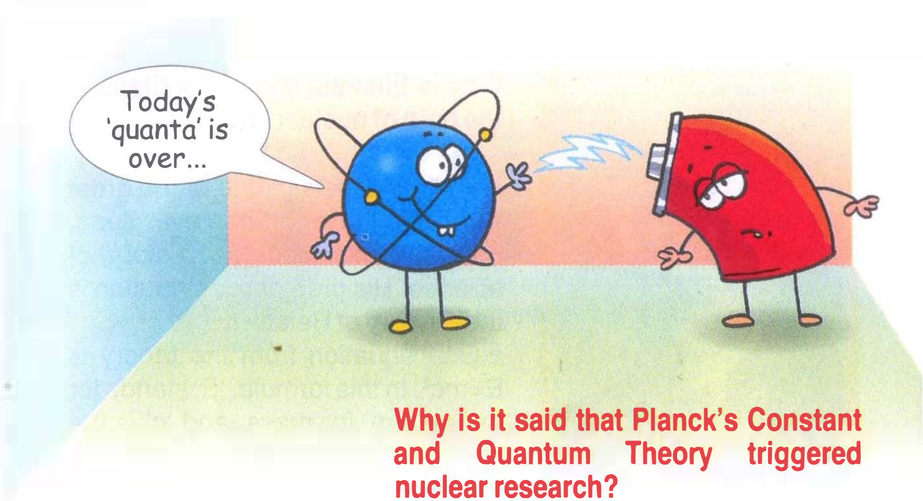
He also observed that radioactive material took the same amount of time for half of it to decay, and called this the 'half-life' of the material.

Most significantly, in 1911, Rutherford created a model of the atom that was simplified in a well known symbol. It showed electrons circling around the nucleus, like planets orbiting the sun.



Natural Radiation

Around 80 percent of the radiation that we are exposed to comes from natural sources. The plants we grow to make our food, the water we drink, and the air we breathe, contain natural radiation.



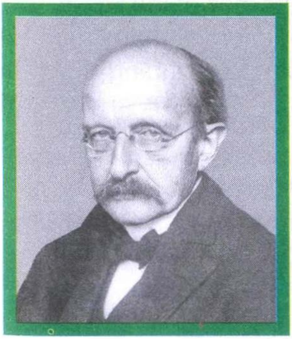
Why is it said that Planck's Constant and Quantum Theory triggered nuclear research?

Max Planck, a German scientist, proposed that atoms could only give out energy in fixed units called quanta.

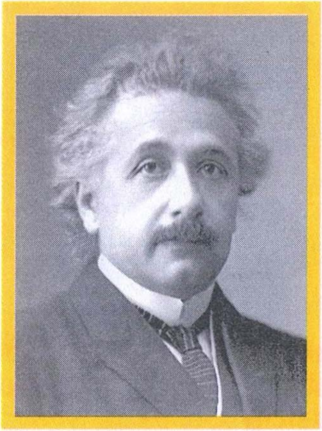
Quanta are packets of energy that exist in lumps or units –but when they travel, they spread out like waves on the surface of a pond. This theory has been developed to explain the behaviour of particles, and the energy they emit.

Planck's Quantum Theory shows that energy behaves as both waves and particles at the same time. Planck also discovered a universal constant known as Planck's Constant.

Planck's Constant and the Quantum Theory represented the birth of a new field of physics known as quantum mechanics, which, in turn, laid the foundation for nuclear research.



Max Planck



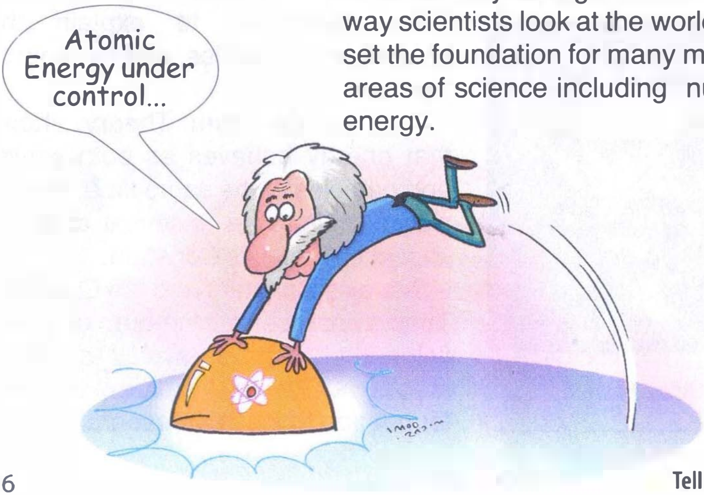
Albert Einstein

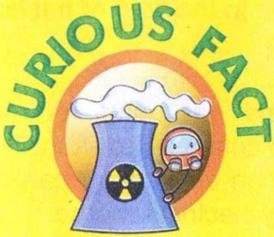
Why is Einstein one of the titans in the field of nuclear energy?

Albert Einstein, one of the great scientists the world has ever seen, has revolutionised the history of science. His greatest contribution is the Theory of Relativity.

One equation from the theory is $E=mc^2$. In this formula, 'E' stands for energy, 'm' for mass, and 'c' is the speed of light, which is a constant, and assumed to be the fastest speed possible in the universe. This formula explains how energy is related to mass. It states that energy and matter are interchangeable. He published the special theory of relativity in 1905, and the general theory of relativity in 1916.

This theory changed much of the way scientists look at the world, and set the foundation for many modern areas of science including nuclear energy.





Bohr's Element

The element bohrium is named after Niels Bohr. It is produced artificially by nuclear fusion, in which an element with larger atoms is produced by fusing together smaller atoms of other elements.

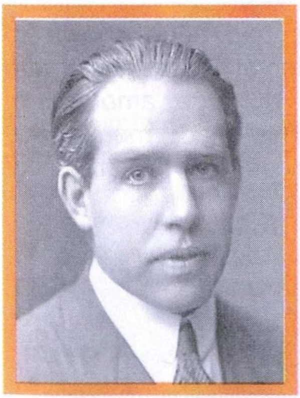
What was Bohr's model of the atom?

Niels Bohr, developed a model of the atom. It consists of a small, positively-charged nucleus orbited by negatively-charged electrons.

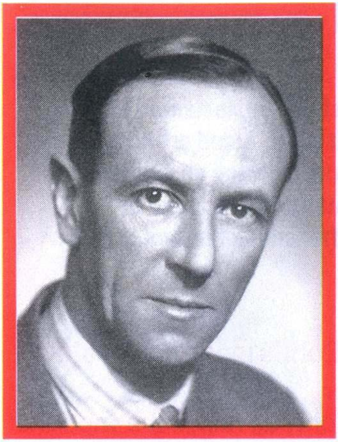
In the Bohr model, the electrons orbiting the nucleus in orbits have a set size and energy. The energy of the orbit is related to its size, with lowest energy found in the smallest orbit.

According to Bohr, radiation is absorbed or emitted when an electron moves from one orbit to another. He also stated that a liquid drop would give a very good picture of the nucleus, and this was to become the 'liquid droplet theory'.

In 1939, Hahn and Strassmann used this theory to help further the understanding of nuclear fission, when they were working on splitting uranium atom- the first step towards the making of a nuclear bomb.



Niels Bohr



James Chadwick

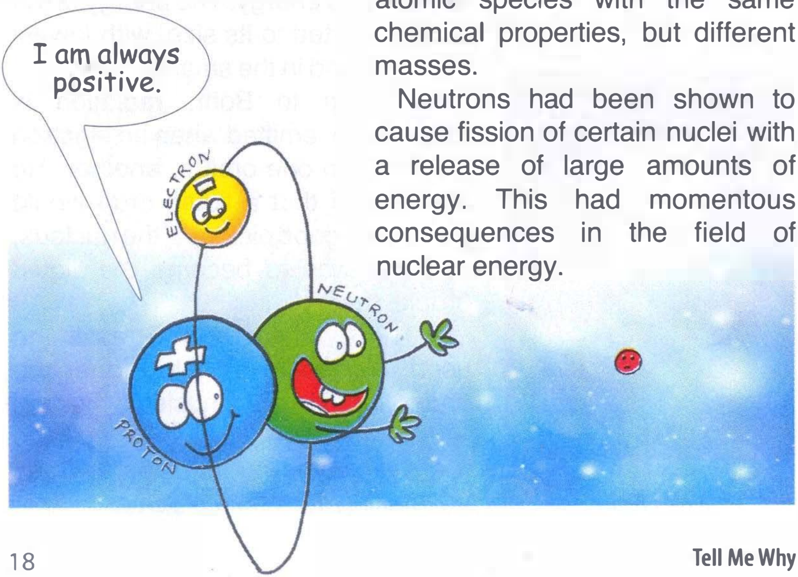
Why is the discovery of the neutron a milestone in the field of nuclear energy?

Neutrons are part of the nucleus, or centre of the atom. The neutron is an elementary particle without any electrical charge.

Neutrons were discovered in 1932, by James Chadwick. The discovery of the neutron dramatically changed the picture of the atom.

The impact of the discovery was such that it completed the understanding of the structure of both the atom, and the atomic nucleus. It also made sense of isotopes or atomic species with the same chemical properties, but different masses.

Neutrons had been shown to cause fission of certain nuclei with a release of large amounts of energy. This had momentous consequences in the field of nuclear energy.



Nobel Family

Marie Curie and her husband Pierre Curie, as well as their daughter Irene and her husband Frederic all are Nobel Prize winners, making them truly a Nobel family!

Frederic

Irene Joliet Curie

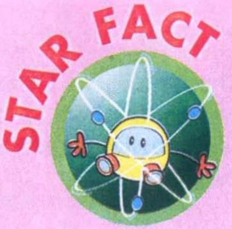
Who discovered artificial radioactivity?

Though radioactivity can be a natural process, it can also be artificially induced.

Irene Joliet Curie and her husband Frederic both were French scientists who shared the Nobel Prize for chemistry in 1935.

They were awarded the prize for artificially synthesizing a radioactive isotope of phosphorous by bombarding aluminium with alpha particles. Their work proved that 'radio-active isotopes' of known elements can be created.

These isotopes rapidly became important tools in biomedical research.



Nobel Chadwick

It was James Chadwick who discovered the neutron. In 1935, he received the Nobel Prize for this important discovery.

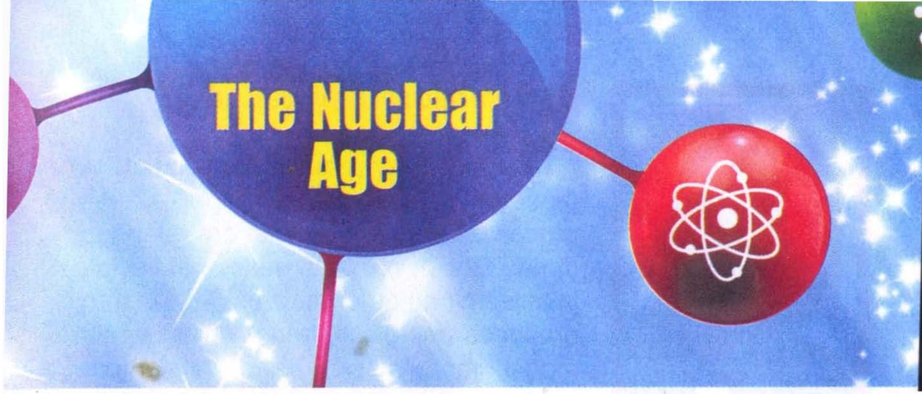
What are the units of radioactivity and radiation?

The Curie family has a word named after them. It is the 'curie' which is a basic unit used for measuring radioactivity.

In the International System of Units the curie has been replaced by the Becquerel, which is written as Bq. It refers to the number of decays per second from a sample of radioactive material, and one decay per second equals one Becquerel.

The basic unit of radiation dose absorbed in tissue is the gray, and one gray represents the deposition of one joule of energy per kilogramme of tissue.

The quantity of material does not indicate how much radioactivity is present. A large quantity of material can contain a small amount of radio-activity, or a small amount of material can have a lot of radioactivity.



The Nuclear Age

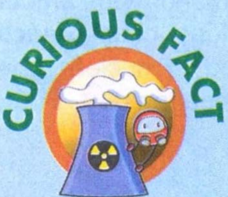
Who discovered nuclear fission?

It was in the early 1930's, that scientists discovered that the atom is made up of proton and neutron particles, in addition to electrons.

In 1938, two German scientists, Otto Hahn and Fritz Strassman and physicist Lise Meitner of Austria, discovered that they could split the nucleus of a uranium atom by bombarding it with neutrons. This is called fission. As the uranium nucleus split, some of its mass was converted to heat energy.

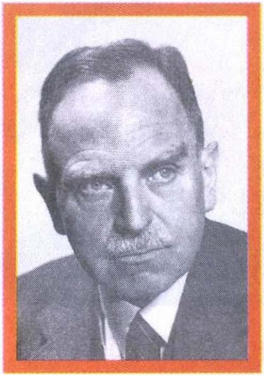
The next step was in 1942, when Enrico Fermi of Italy, noticed that the fission of one uranium atom gave off more neutrons which could in turn split other uranium atoms, starting a chain reaction. This meant that enormous amounts of energy could be produced by this process of nuclear fission.

Otto Hahn and Enrico Fermi both won Nobel prizes for their work.



Star Element

In 1789, a German chemist, Martin Klaproth, discovered uranium in a mineral called pitchblende.

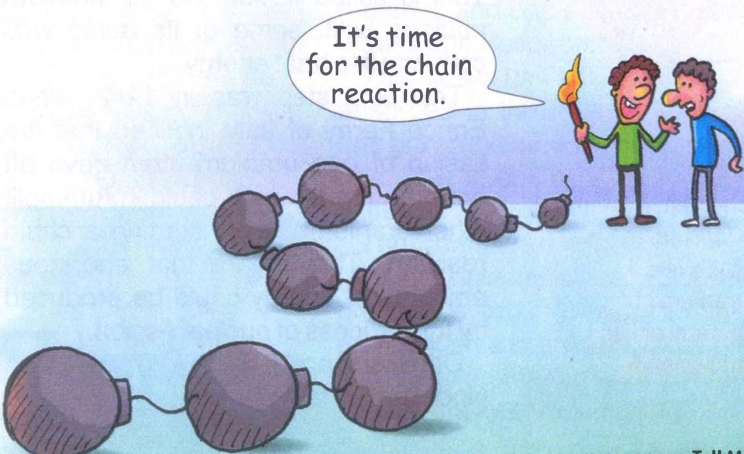


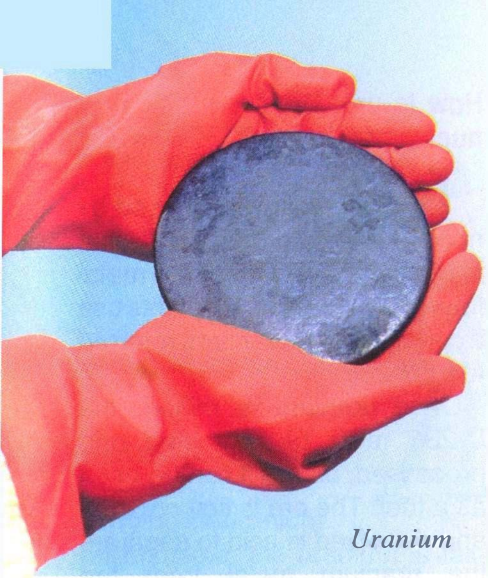
Otto Hahn

What are nuclear chain reactions?

Nuclear chain reactions are one of the modern applications of the fission process. The neutrons that are released during fission produce additional fission in at least one other nucleus. This in turn produces more neutrons which again trigger more fission- and thus more neutrons- to set a chain reaction into motion.

Heavy unstable elements like plutonium or uranium have far more neutrons than protons in their nucleus. When they are exposed to even more neutrons, they become even more unstable, and split up through fission- producing yet more neutrons, along with enormous amounts of energy. Nuclear chain reaction processes are used in nuclear power plants and nuclear weapons.





Uranium

Why is uranium used for nuclear experiments?

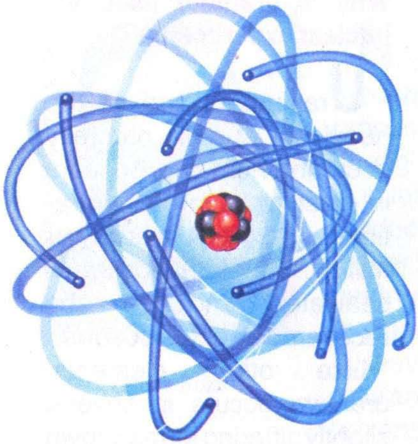
Uranium is one of the heaviest of all naturally occurring elements. It occurs in most rocks in concentrations of 2 to 4 parts per million. Uranium occurs in seawater, and can be recovered from the oceans.

Like other elements, uranium occurs in several slightly differing forms known as 'isotopes'. The isotope U-235 is important, because under certain conditions it can readily be split, yielding a lot of energy.

When the nucleus of a U-235 atom is hit by a moving neutron it splits in two, and releases some energy. Two or three additional neutrons are also thrown off. If enough of these expelled neutrons cause the nuclei of other U-235 atoms to split, releasing further neutrons, a fission 'chain reaction' can be achieved. Hence, uranium is widely used in nuclear experiments.

Energy Giant

A pellet of uranium the size of your fingertip has as much energy as 481.38 cubic metres of natural gas, 807.4 kg of coal, or 564 litres of oil. Amazing, isn't it?

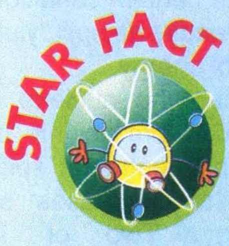


How is uranium ore turned into nuclear fuel?

The fuel most widely used by nuclear plants for nuclear fission is uranium. It is a common metal found in rocks. Nuclear plants use a certain kind of uranium, referred to as U-235.

Once uranium is mined, the U-235 must be extracted and processed, before it can be used as a fuel. The ore is first crushed and dissolved in acid to separate the uranium metal from the unwanted rock material.

In another method, boreholes are drilled down to uranium-bearing rock. A solvent is pumped down one hole. The solvent



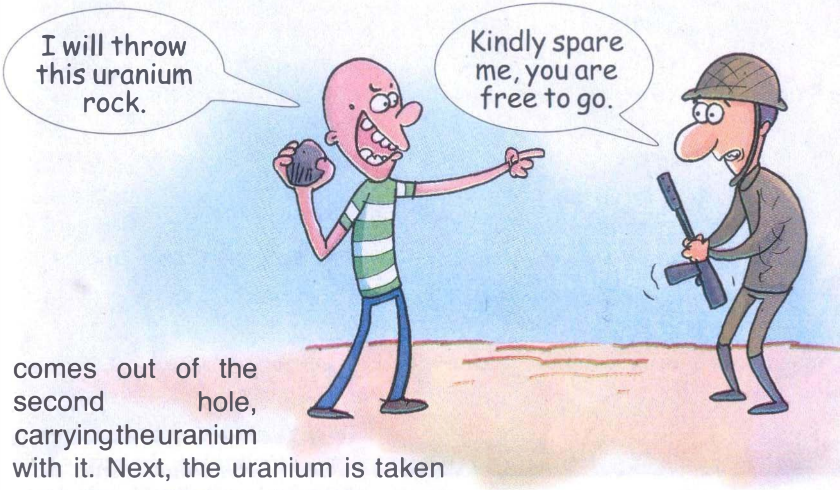
Life for Science

Marie Curie dedicated her life to the study of radioactivity- and Marie gave her life for it too. She died in 1934, of leukemia that was caused by long term exposure to radiation.

From where does uranium originate?

Uranium, which was identified as an element in 1789, was named after the then newly discovered planet Uranus.

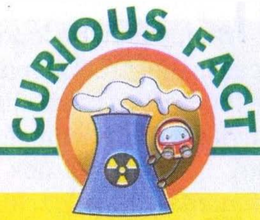
Uranium is found not just on Earth, but also in space and on other planets. This is because uranium only forms inside supernovas- or exploding stars- and



comes out of the second hole, carrying the uranium with it. Next, the uranium is taken out of the solution as uranium oxide, which is known as yellowcake. This is then transported to conversion plants, where it is changed into uranium dioxide, which is used as a reactor fuel.

because it has so many protons and neutrons in it, it doesn't form very easily.

The Earth's uranium was produced when one or more stars exploded over six billion years ago. When these explosions occurred, the materials that were produced became a part of the solar system, of which the Earth too is a part. The uranium in space later became a part of the Earth's continental crust.



Lots of Ore

You need around 50,000 tonnes of uranium ore to make 25 tonnes of nuclear fuel, which is roughly the amount of nuclear fuel that a 1,000-megawatt nuclear power plant needs every year.

A Uranium Mine

Where is uranium found on Earth?

Uranium can be found in very small traces in most rocks and in the ocean.

In the Earth's crust, uranium is found in minerals. Uranium deposits occur in many different rock types from sedimentary to volcanic. Since it is not found in a pure form, it has to be extracted from other elements.

Uranium has three naturally occurring isotopes. Uranium-238 is the most stable, and makes up over 99 percent of the naturally occurring uranium. Several countries have significant uranium resources. Kazakhstan is the world's top uranium producer. In India we have uranium mines in Jharkand, Meghalaya and Andhra Pradesh.

Plutonium

The element plutonium is made from uranium through a nuclear process. Only a tiny amount of it exists in nature.

Why is plutonium important?

Plutonium is an extremely rare element in the Earth's crust. It is so rare that for many years it was thought that it did not occur naturally.

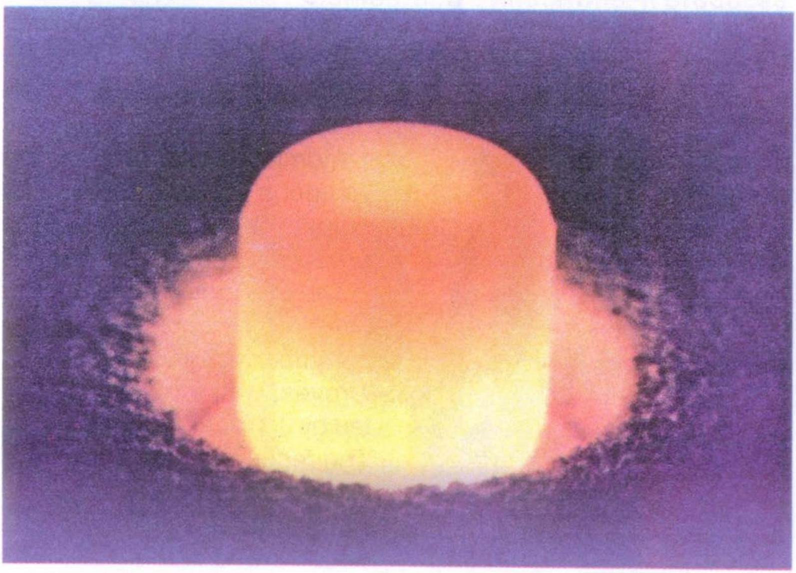
The main source of plutonium is uranium-238, which is used in nuclear reactors. Large quantities are produced each year by this process.

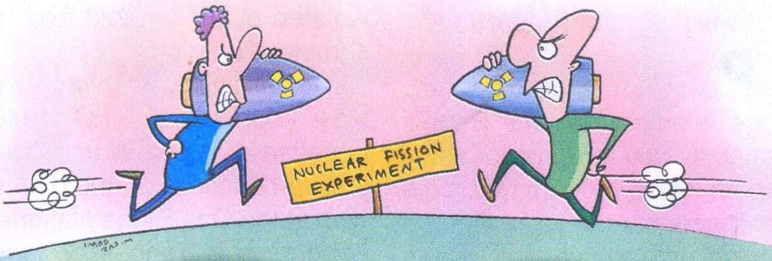
Plutonium was discovered by a team of scientists at the Berkeley Radiation Laboratory in California in 1940.They isolated plutonium-238 from a sample of uranium.

The discovery of plutonium was kept secret until 1946 because of World War II. The first production of plutonium was at the Oak Ridge National Laboratory in Tennessee, and was used to make a nuclear bomb.

Plutonium is used in both nuclear reactors and nuclear weapons.

A Glowing Cylinder of Plutonium





Why did the discovery of nuclear fission affect the course of World War II?

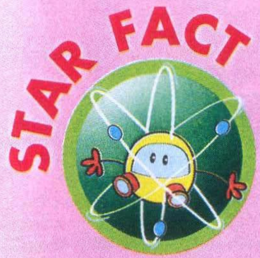
Physicists first split the atom in 1938, in the process known as nuclear fission.

When World War II broke out, scientist all over Europe started working on nuclear fission programmes. American scientists too tried to work together so that they could easily and quickly create fissionable materials for a nuclear bomb.

General Groves with Oppenheimer.

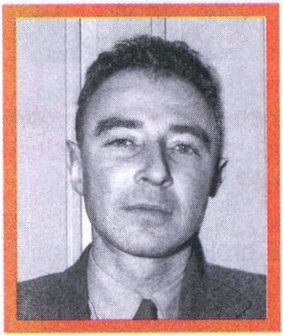
Atomic bombs are nuclear weapons that use the energy output of nuclear fission to produce massive explosions.

The US Army decided to take over the project under command of General Leslie Groves, with a research team led by J. Robert Oppenheimer. The result of their research led to the bombs that destroyed Hiroshima and Nagasaki and ended World War II.

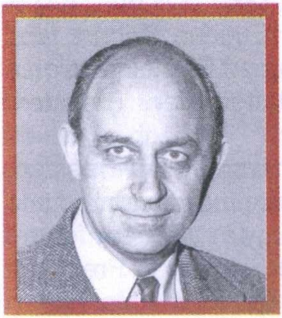


The Change

During chemical reactions, energy is released in the form of heat, and the atoms remain unchanged. During a nuclear reaction, energy is released in the form of radioactivity, and the atoms involved in the reaction change.



Robert Oppenheimer



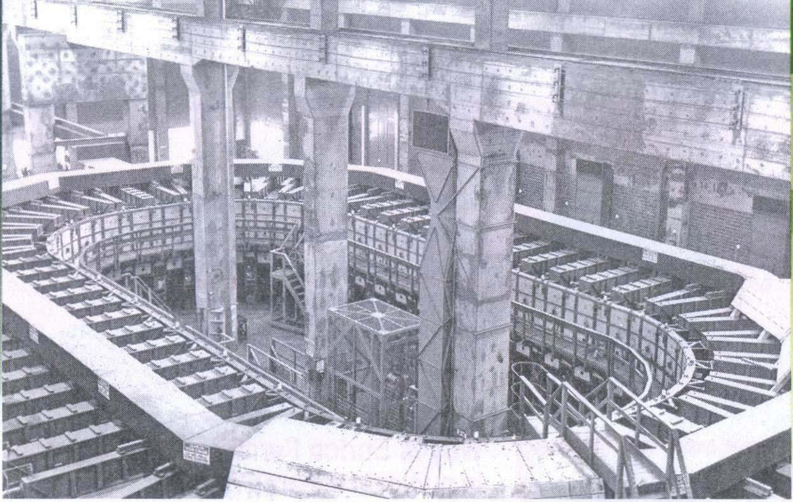
Enrico Fermi

Why is Enrico Fermi one of the greats in nuclear research?

It was Enrico Fermi who discovered that when a radioactive substance such as uranium is bombarded by neutrons, it produces by-products that are not uranium, and are lighter than the original sample.

In 1935, he bombarded uranium – which is considered to be element 92- with neutrons, and produced what appeared to be element 93 and element 94.

He won the Nobel Prize in 1938 for his work in radioactivity, and this allowed him to escape from Italy during World War II, and settle in the United States. He then built the first nuclear reactor, and worked on the Manhattan Project. Fermi died in Chicago in 1954. Element 100, fermium, is named in his honour.



An inside view of a reactor, Manhattan Project.

What was the significance of Einstein's letter to President Roosevelt as far as nuclear research was concerned?

When World War II broke out, Germany had a two-year head start on developing nuclear energy.

The Americans feared that the Nazis would shape it into a weapon of mass destruction.

In August 1939, Leo Szilard, fellow Hungarian physicists Eugene Wigner and Edward Teller urged Albert Einstein to sign a letter they had drafted for President Roosevelt.

In this letter, Einstein warned the President that the element uranium may be turned into a new source of energy in the near future. This letter from Albert Einstein to President Franklin D. Roosevelt led to 'the Manhattan Project,' - a national crash program to develop atomic weapons ahead of Nazi Germany.

STAR FACT

Not Harmful

Though natural uranium is radio-active, it is not dangerous. This is because it decays so slowly that it does not do harm.

What is the Manhattan Project?

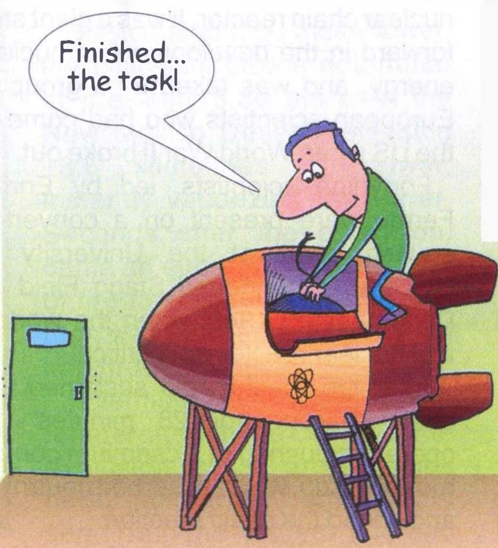
The Manhattan Project was the name for the research and development program for the atomic bomb in the United States. It was started in 1940.

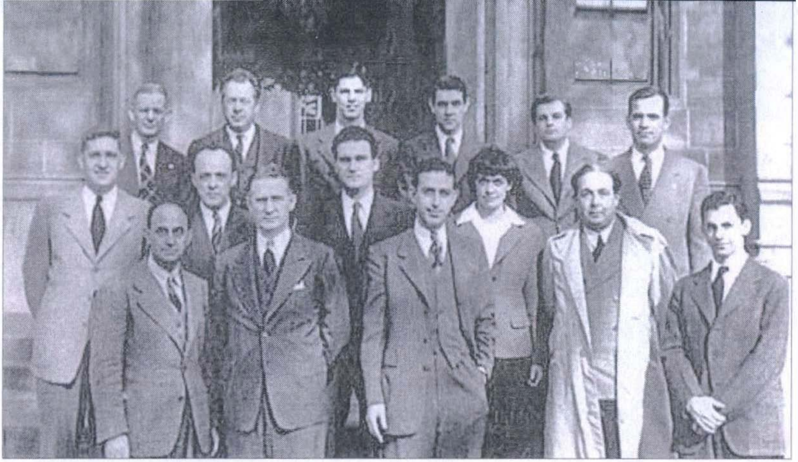
Ironically, many of the scientists involved in making the bomb had defected from Germany.

On July 16th, 1945, the first atomic bomb was exploded in the New Mexico desert. The explosion was massive.

Scientists figured that the temperature at the centre of the explosion was three times hotter than at the centre of the sun.

Although the scientists were happy that they had successfully made the bomb, they also were sad and fearful. This bomb would cause mass destruction and death.





Reunion of Scientists involved with the Chicago Pile -I Reactor

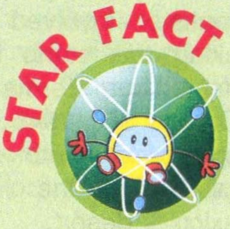
Why is the Chicago Pile very interesting?

The Chicago Pile, also called CP-1, was the first selfsustaining, controlled nuclear chain reactor. It was a giant step forward in the development of nuclear energy, and was taken by a group of European scientists who had come to the US when World War II broke out.

Fortynine scientists, led by Enrico Fermi, were present on a converted squash court at the University of Chicago's abandoned Stagg Field on December 2nd 1942, when the world's first nuclear reactor went critical.

After the reactor had sustained the chain reaction for 28 minutes the operators pushed in a cadmium control rod called zip, which absorbed neutrons, and ended the chain reaction.

In 1943, CP-1 was dismantled, and moved to a less-populated site.

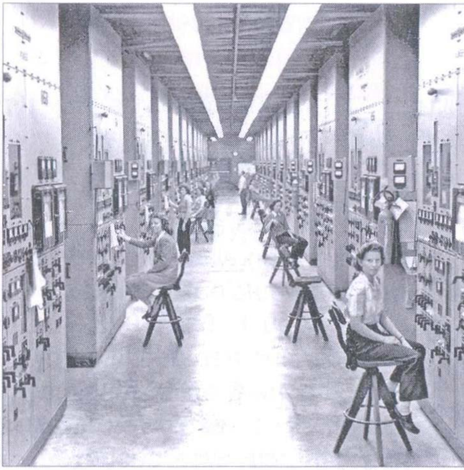


Global Energy

Nuclear energy is today used in more than 30 countries around the world.

Why does the Trinity Test mark the beginning of the nuclear age?

Trinity was the code name of the first detonation of a nuclear device. This test was conducted by the United States on July 16th, 1945. It was on this day that a plutonium bomb was tested at a site in Los Alamos.



Workers at Manhattan Project

Trinity Test

Hoisted atop a 50 metre tower, the plutonium device detonated at precisely 5.30 am over the New Mexico Desert, releasing 18.6 kilotonnes of power, instantly vaporizing the tower. Seconds after the explosion, came an enormous blast. A ball of fire tore up into the sky, and then was surrounded by a giant mushroom cloud.

Scientists figured that the temperature at the centre of the explosion was three times hotter than at the centre of the sun. Thus the nuclear age had begun.

Why are Hiroshima and Nagasaki great tragedies in the history of mankind?

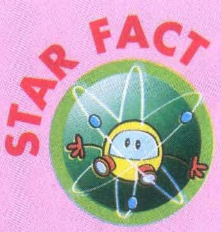
By the time the first atomic bomb had been made, Germany had already surrendered. Japan was defeated as well, but would not surrender.

On August 6th, 1945, an atomic bomb named Little Boy was dropped on Hiroshima, Japan. The explosion was huge, the city was destroyed, and eighty thousand people were killed.

The bomb was dropped by a plane named the Enola Gay which was piloted by Colonel Paul Tibbetts. Despite witnessing the terrible destruction of the bomb on Hiroshima, Japan still refused to surrender.

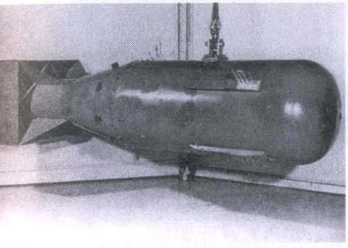
Three days later, on August 9th, 1945, another atomic bomb, nicknamed Fat Man, was dropped on Nagasaki, Japan. Forty thousand people were killed. Six days after the bombing of Nagasaki, Japan surrendered and World War II was over- but with tragic results.

Mushroom Cloud formed at Nagasaki, immediately after the bombing.



Nuclear Plants

Globally, there are over 430 commercial nuclear power reactors in 31 countries. A nuclear power plant must shut down every 18-24 months to remove its used uranium fuel, or radioactive waste.



Replica of Little Boy

What is Little Boy?

'Little Boy,' was the first nuclear weapon used in warfare. It was a gun-type weapon, which detonated by firing one mass of uranium down a cylinder into another mass to create a self-sustaining nuclear reaction.

The bomb itself was relatively small despite its huge explosive capability. The heat created was so great that clothes caught fire on people over two kilometres from the centre of the explosion.

'Little Boy' also created ultra high pressure. The wind speed on the ground directly beneath the explosion was so high, that barely any buildings were left standing.

Radiation poisoning killed many people in the city. Nearly all the people who survived the bomb blast, but lived within 800 metres of it, died within 30 days. Death from radiation exposure continued for many years.

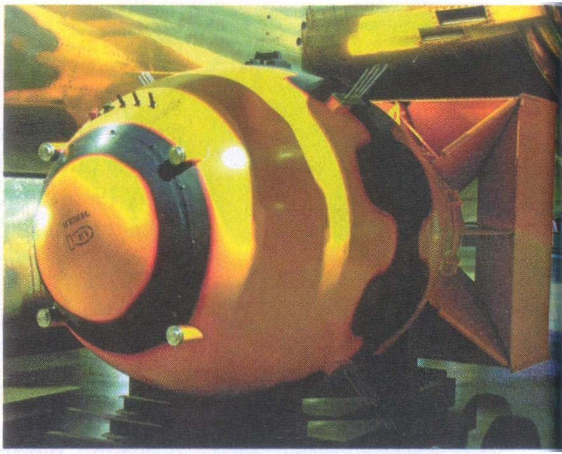
What is Fat Man?

'Fat Man' was the atomic bomb that was dropped over Nagasaki, Japan, on August 9th, 1945, near the end of World War II.

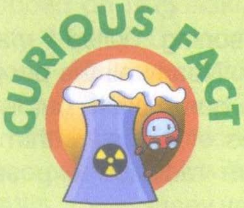
At 11:02 a.m. the American B-29 Superfortress 'Bockscar,' in search of the shipyards, spotted the Mitsubishi Arms Works through a break in the clouds. It dropped the nuclear bomb Fat Man, the second nuclear weapon to be detonated over Japan, on this target.

Because of Nagasaki's hilly terrain, however, the damage was somewhat less extensive than on the relatively flat Hiroshima. However, it still leveled nearly half the city. Around 75,000 residents were killed, followed by the death of at least as many from resulting sickness and injury.

If those who died from radioactive materials causing cancer, is taken into account, the total number of casualties is believed to be at least 100,000 killed residents.



Replica of Fat Man



Largest Producer

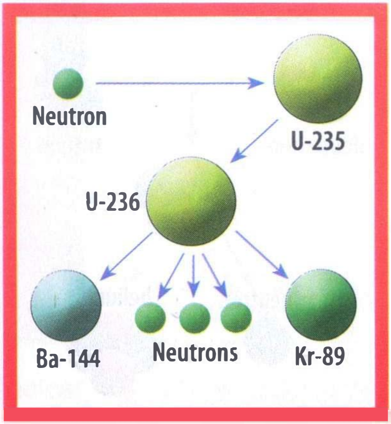
The largest producers of nuclear energy are the USA, France and Japan. Of the three, the USA is the world's largest producer of nuclear power.

What is nuclear fission?

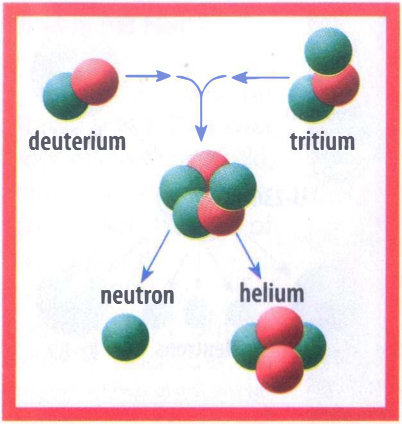
When an atom splits into two parts, it releases energy. This process is known as fission. An atom contains protons and neutrons in its central nucleus. In fission, the nucleus splits, either through radioactive decay, or because it has been bombarded by other subatomic particles known as neutrinos. The resulting pieces have less combined mass than the original nucleus. The missing mass is converted into nuclear energy.

Controlled fission occurs when a very light neutrino bombards the nucleus of an atom, breaking it into two smaller, similarly-sized nuclei.

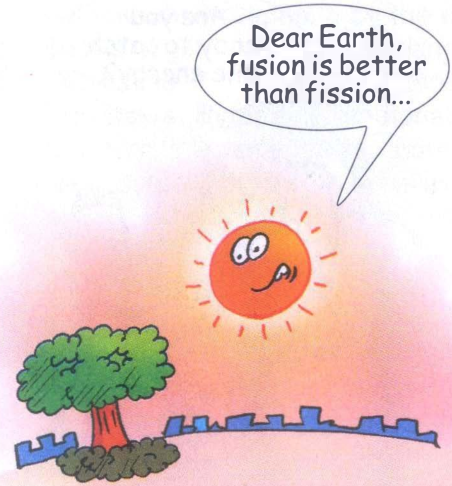
The destruction releases a significant amount of energy – as much as 200 times that of the neutron that started the procedure – as well as releasing at least two more neutrinos. Controlled reactions of this sort are used to release energy within nuclear power plants. Uncontrolled reactions can fuel nuclear weapons.



Nuclear Fission



Nuclear Fusion



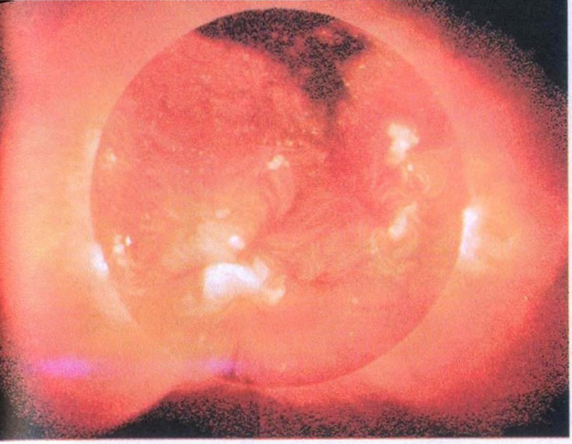
What is nuclear fusion?

Nuclear fusion is an atomic reaction in which multiple atoms combine to create a single, more massive atom. The resulting atom has a slightly smaller mass than the sum of the masses of the original atoms. The difference in mass is released in the form of energy during the reaction.

The most common nuclear fusion reaction in the universe, and the one of most interest to scientists, is the merging of hydrogen nuclei to form helium nuclei. This is the process that occurs in the interiors of stars including the Sun.

Nuclear fusion requires extremely high temperatures. Scientists can generate the high temperatures and forces required to produce uncontrolled hydrogen fusion, the most notable example being the hydrogen bomb.

However, sustaining these temperatures and forces, in order to construct a hydrogen fusion reactor, has proven difficult.



Core of the Sun - A Visualisation

What are the fuels used for nuclear fusion?

Nuclear fusion powers the Sun and other stars, as hydrogen atoms fuse together to form helium, and matter is converted into energy.

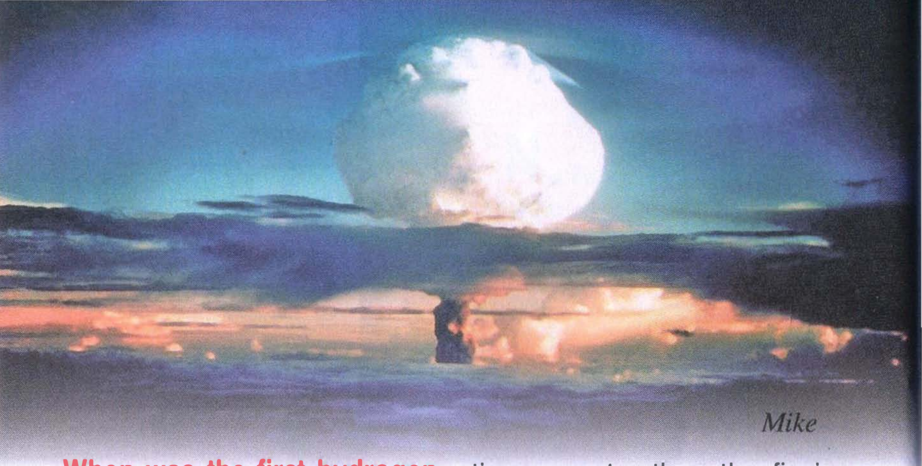
On Earth, a fusion reaction is most readily feasible between the nuclei of the two heavy forms or isotopes of hydrogen – deuterium and tritium. Deuterium, also called heavy hydrogen, is a stable isotope of hydrogen, with a natural abundance in the oceans of Earth. It is used in nuclear fusion reactions, in the presence of tritium, to produce high energy yield.

Tritium is an isotope of hydrogen. Tritium is produced naturally in the upper atmosphere when cosmic rays strike nitrogen molecules in the air.

One atom of deuterium and one atom of tritium combine to form a helium-4 atom and a neutron.

Nuclear Fuel

The mining, enrichment and transportation of uranium generates harmful by-products, but the nuclear power plants themselves do not give off any harmful gases.

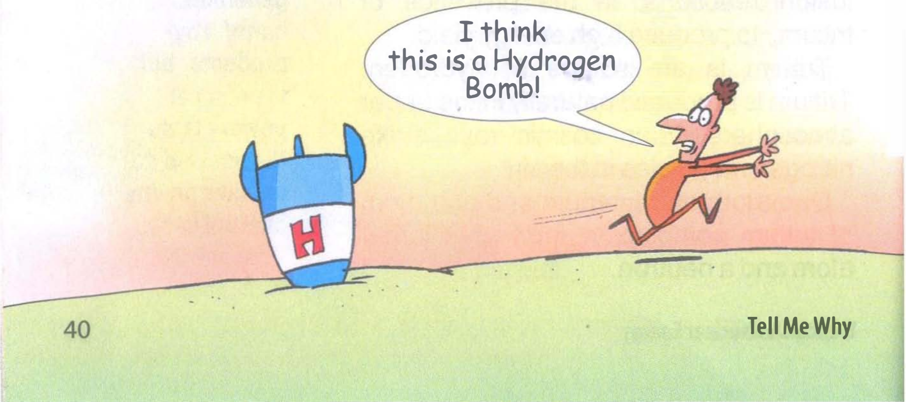


Mike

When was the first hydrogen bomb tested?

It was a physicist at Los Alamos, Edward Teller, who first suggested a thermonuclear fusion- or a hydrogen bomb.

On November 1st, 1952, the US detonated the world's first hydrogen bomb, code-named 'Mike,' on the Enewetak Atoll of the Marshall Islands. The resulting explosion was 700 times greater than the fission bomb dropped on Hiroshima. The cloud produced by the explosion was 40 kliometres high and 150 kilometres wide, and the island on which it exploded, simply disappeared, leaving nothing but a gaping crater. The Soviet Union exploded a thermonuclear device the following year, and by the late 1970s, seven nations had developed hydrogen bombs.



Amazing Fusion

Just a teaspoon or so of tritium and deuterium can produce a lifetime's worth of electricity for one person when nuclear fusion takes place.

What is a nuclear reactor?

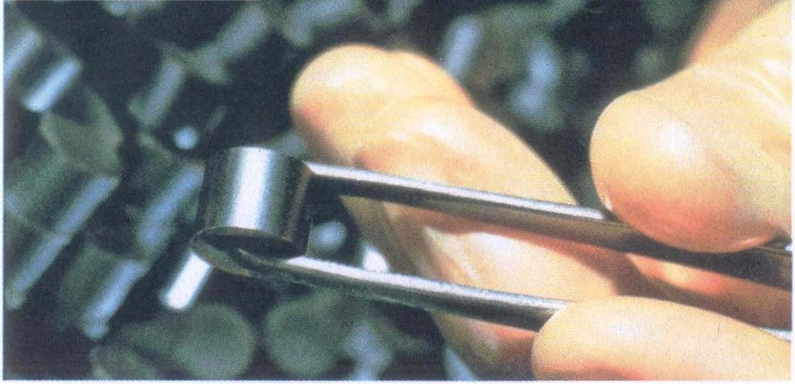
A nuclear reactor is an apparatus in which nuclear fission chain reactions are initiated, controlled, and sustained at a contained rate.

Nuclear power comes from heat that is generated during nuclear fission, when one atom splits into two. Most nuclear power plants use enriched uranium and plutonium as fuel.

Inside a nuclear reactor are several rods of uranium. The uranium is used to boil water and produce steam. The steam drives turbines that produce electricity. Rods of graphite are used to control the nuclear reaction within the uranium.

To put it in a nutshell, in a nuclear reactor, the heat that is given off from the reaction is used to heat water, which creates steam, which drives the turbine, which spins a generator to produce power.

Control Room of a Reactor



Nuclear Fuel Pellets

What are the components of a nuclear reactor?

A nuclear reactor produces, and controls the release of energy from splitting the atoms of certain elements.

The fuel, the control rods, the coolant, and the moderator are the basic components of a nuclear reactor.

In a nuclear power reactor, the energy released is used as heat to make steam to generate electricity. Uranium is the basic fuel. Usually pellets of uranium oxide are arranged in tubes to form fuel rods.

The reactor also contains a moderator, which is the material in the core which slows down the neutrons released from fission, so that they cause more fission.

There are also control rods that are made with neutron-absorbing material such as cadmium, hafnium or boron.

In addition, reactors use a coolant which circulates through the core so as to transfer the heat from it.

Shutdown Rods

A nuclear reactor also has shutdown rods. These are used to stop the chain reaction if an emergency arises.

Why are control rods important in a nuclear reactor?

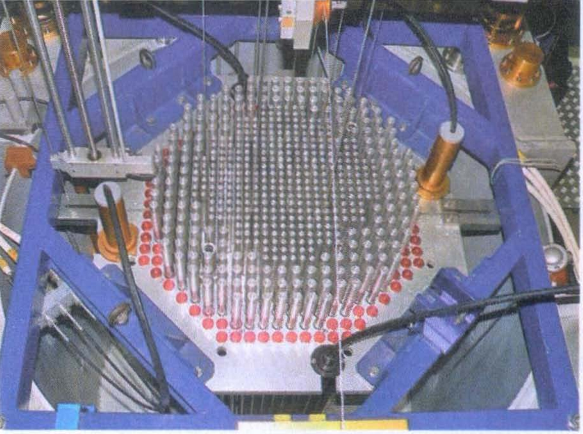
Control rods are made of materials such as carbide or alloys of silver, indium and cadmium, hafnium, or boron.

By absorbing neutrons, a control rod controls fissions in the chain reaction that is started when materials like uranium are bombarded by subatomic particles.

To prevent overheating in a nuclear reactor, control rods are made up of a material that absorbs neutrons. They are inserted into the uranium bundle using a mechanism that can raise or lower them. Raising and lowering the control rods allow operators to control the rate of the nuclear reaction.

The rods can also be used to shut the reactor down in the event of an accident or to change the fuel.

Core of a Nuclear Reactor



Core of an Experimental Reactor

Why is a shield used in a nuclear reactor?

Since a nuclear reactor is 'highly radio-active,' especially when operating at high power levels, producing a lot of penetrating gamma rays and neutrons, radiation workers need to be protected from the radiation.

So 'shielding' materials of some kind are used, and these depend on the design of the reactor and the power levels. Most commercial nuclear plants can rely on concrete and distance - the farther away you are, the less damaging the radiation- to reduce the radiation levels where people work.

Another good shielding material is lead. Water is also a good shield for neutrons, since the neutrons bounce off the hydrogen, and give up a lot of their energy with each collision.

Fission Product Heating

Chain reactions in a nuclear reactor can be stopped by using the control rods, but even after a reactor has been shut down, it will continue to produce heat. This is called fission product heating.

What is spent fuel?

Nuclear power plants generate two types of waste known as high-level and low-level wastes.

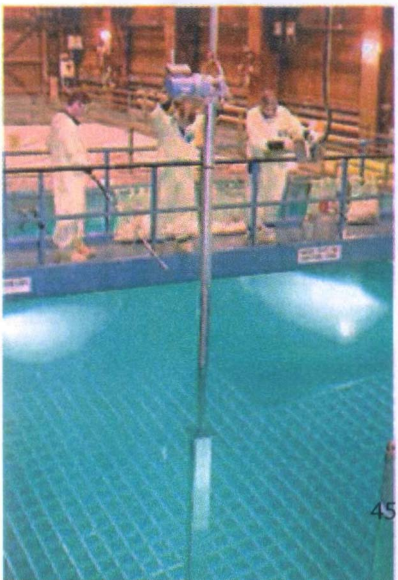
High-level waste includes the fuel that was used in the nuclear reactor, called 'spent fuel.' It is highly radioactive, and is very dangerous. Spent fuel consists of uranium, plutonium and a variety of fission products, and is about 100 million times more radioactive than fresh fuel, because all the fission products are themselves radioactive. Spent fuel can either be stored, or it can be reprocessed.

To store spent fuel, it must be cooled for several years in deep pools inside the plant, after which it can be transferred to special casks, which are like big, concrete barrels.

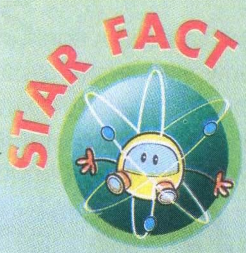
Some of the fission products in the spent fuel will take many years to lose their radioactivity.

Low-level waste can be shipped to low-level waste disposal facilities. There, it is packaged, buried in trenches, and covered with soil.

Spent Fuel Pool



Obninsk Power Plant - Museum



First in the USA

The first commercial nuclear generator in the United States was located in Pennsylvania. It is the Shippingport Reactor that was established in 1957.

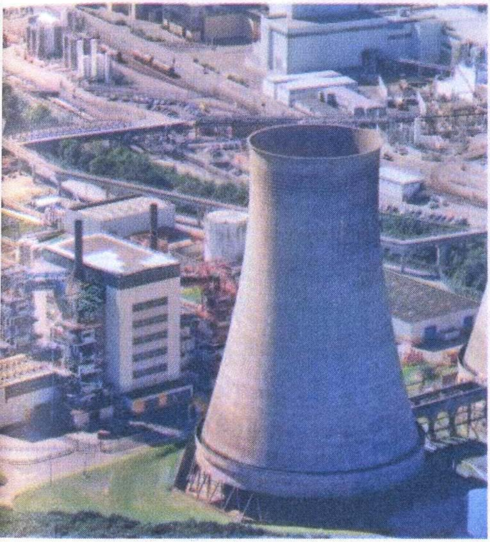
Why is the Obninsk Power Plant famous?

Obninsk was established in 1946 based on a decree by Josef Stalin that a secret laboratory to carry out research in nuclear physics should be built on the left bank of the Protva River, a tributary of the Oka.

The facility was built in secrecy, and even workers did not know exactly what they were constructing. German scientists captured during the war, along with their Soviet colleagues, came to work in this organization.

As a result, the world's first nuclear power plant was unveiled here in 1954 — in the midst of the Cold War.

For around four years, till the opening of Siberian Nuclear Power Station, Obninsk remained the only nuclear power reactor in the Soviet Union. The power plant remained active until April 29, 2002, when it was finally shut down.



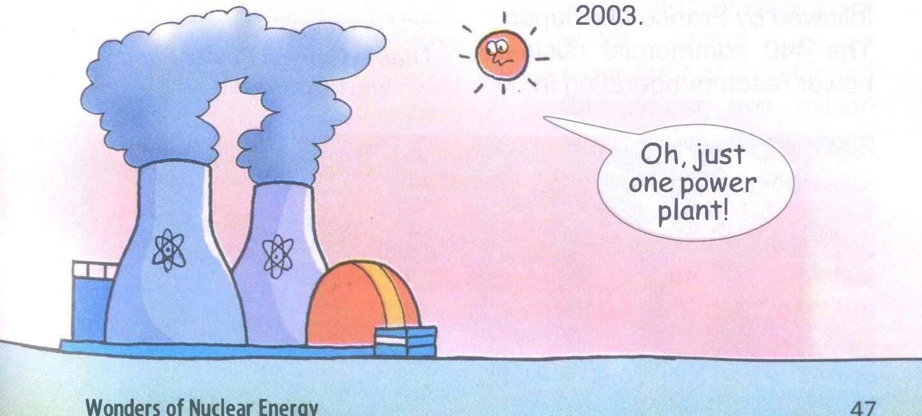
Calder Hall Nuclear Reactor

Which is the first commercial power plant?

Calder Hall Nuclear Station made history in 1956 by producing the world's first electric power generation on a commercial scale - while also producing plutonium for weapons.

Reactor No.1 was opened officially by Queen Elizabeth II on 17th October 1956, and Workington, 24 km away, became the first town in the world to receive electricity produced using nuclear power. The first two reactors began operating in 1956, the third in 1958, and the fourth in 1959.

Calder Hall ceased power generation on 31st March 2003.



STAR FACT

Nuclear Waste

In the USA, a permanent storage site for nuclear waste has been selected at Yucca Mountain, Nevada. Yucca Mountain is an extremely dry area of Nevada.

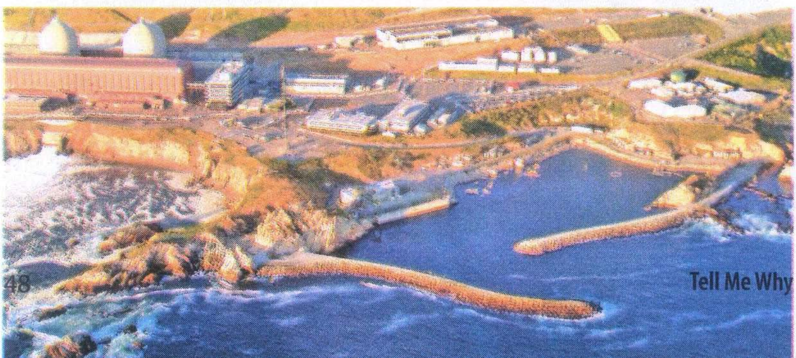
How many nuclear reactors are there in the world now?

Nuclear power has kept growing in recent decades, despite some setbacks. Between 1996 and 2009, 49 new nuclear reactors started operation, and 43 reactors were retired, according to the World Nuclear Association.

Currently, the world as a whole has 440 operating nuclear reactors. The United States has by far the most, followed by France and Japan. The 440 commercial nuclear power reactors operating in 30 countries have 377,000 MWe of total capacity. They provide about 14 per cent of the world's electricity as continuous, reliable base-load power, and their efficiency is increasing.

56 countries operate a total of about 250 research reactors, and a further 180 nuclear reactors power some 140 ships and submarines. Sixteen countries depend on nuclear power for at least a quarter of their electricity.

Diablo Canyon Power Plant, California

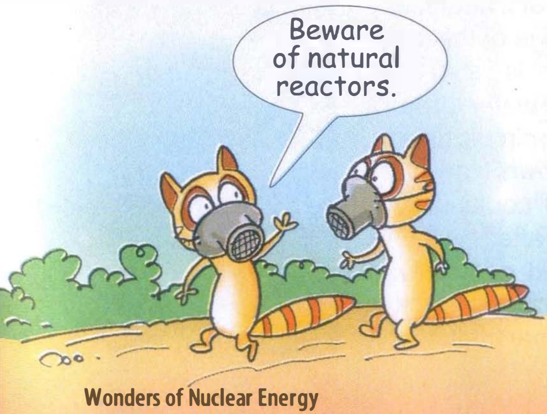


Nuclear Power Plant at Qinshan, China

What are natural reactors?

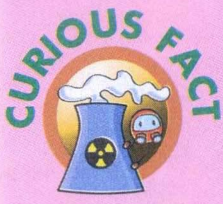
Our Earth holds many surprises- and perhaps the most surprising of all is the presence of a natural nuclear reactor!

In 1972, the remains of a natural, spontaneously formed uranium reactor were found in ancient rocks of the African nation of Gabon, in the Oklo uranium mine.



Scientists say that about 1.7 billion years ago, a natural deposit of uranium ore was radioactive enough to generate about 100 kilowatts of heat, off and on. The chain reaction started spontaneously ,with the presence of water acting as a moderator and continued for almost two million years before finally dying away.

During this long reaction period, about 5.4 tonnes of fission products as well as 1.5 tonnes of plutonium were generated.



No Waste

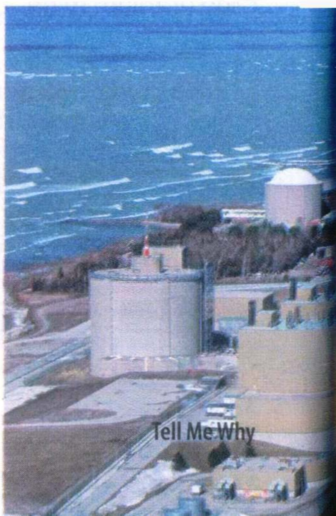
Nuclear power generates very little waste. The radioactive waste resulting from the production of a lifetime of electricity for one person can be contained in a glass ball the size of your hand.

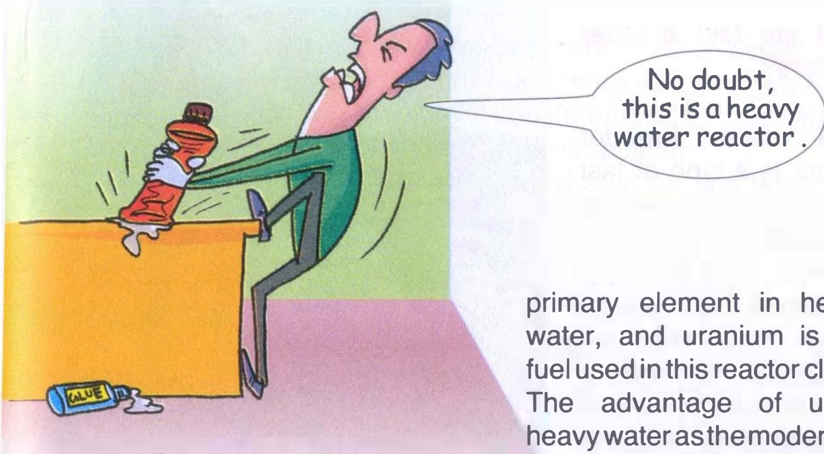
What is a pressurized water reactor?

The most common type of nuclear reactor is the pressurized water reactor or PWR. It uses ordinary water both as a neutron moderator and as a coolant. There is a primary circuit that flows through the core of the reactor at very high pressure, and a secondary circuit in which steam is generated to drive the turbine.

Water in the reactor core reaches about 325 degrees Celsius, and therefore, it must be kept under 150 times atmospheric pressure to prevent it from boiling.

To put it in very simply, PWRs keep water under pressure so that it heats, but does not boil. The advantage of this type of reactor is that water is also the moderator, and if any of the water turns to steam in the primary cooling circuit, fission would automatically slow down. However, if the reactor loses all its coolant, it is dangerous, because even after fission is stopped, the reactor would continue to generate heat from radioactive decay, and this could cause a nuclear meltdown.





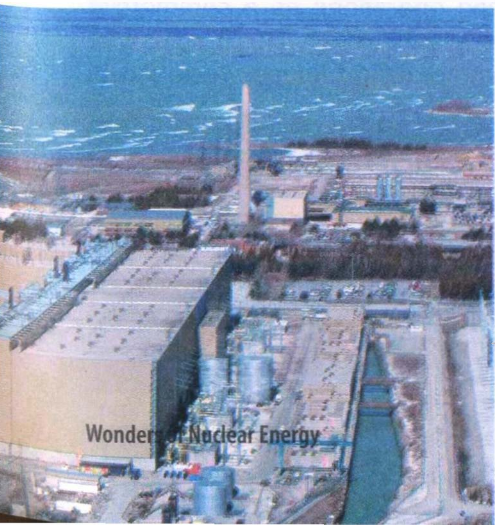
What is a heavy water reactor?

Heavy water reactors are similar to PWRs, but use water enriched with deuterium- an isotope of hydrogen- as the moderator and coolant.

This type of water is called 'heavy water'. Deuterium is the primary element in heavy water, and uranium is the fuel used in this reactor class. The advantage of using heavy water as the moderator is that natural, unenriched uranium can be used to drive the nuclear reactor.

This type of reactor is called the CANDU, and got its name because this heavy water reactor design was developed in Canada.

Other nations with this type of reactor include India, South Korea, Romania, Pakistan, Argentina, and China. It is estimated that power plants using the CANDU design generate more than 23,000 megawatts, about 21 per cent of the electricity produced by nuclear energy.



A CANDU Reactor

What are fast breeder reactors?

A fast breeder reactor is a type of fast neutron reactor produces more fissile material than it consumes. It has a design that uses no moderator. Instead, it relies on fast neutrons to sustainitschainreaction. This requires high grade fuel such as plutonium, or enriched uranium.

Superphenix, Worlds Largest Fast Breeder Reactor

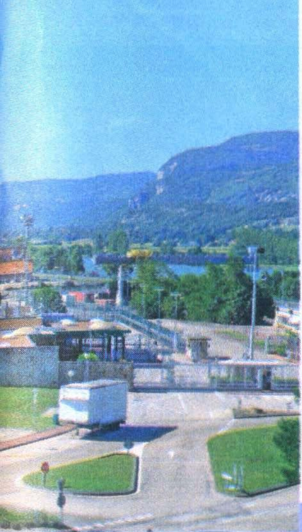
What was Superphenix?

The Superphenix was the world's first commercial fast breeder reactor. This nuclear power station was located on the river Rhone in France, close to the border with Switzerland.

It was put into service in 1984, and ceased operations as a commercial power plant in 1997. This reactor was a commercial prototype, designed to

Boiling Water Reactor

The Boiling Water Reactor or BWR is a type of nuclear reactor mainly in the USA and Sweden. In this reactor, water is used both as the coolant and moderator.



The reactor core has a fissile zone, surrounded by a fertile area in which natural uranium is transformed into plutonium. The liquid refrigerant is sodium.

Once the initial start up has begun, the reactor produces its own fuel and that can be used to start other fast breeder reactors. This is why it is called a 'breeder'.

solve all of Europe's energy problems, as it has the ability to product more plutonium fuel than it consumed - hence the name 'fast-breeder'.

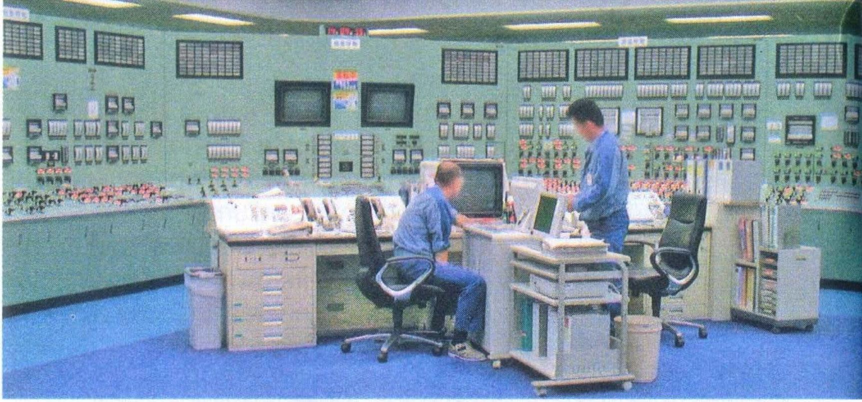
The Superphenix was designed to hold an initial core of 5,550 kilogrammes of plutonium.

However, the reactor faced massive delays, maintenance costs, numerous closures, and was eventually decommissioned ten years after it was commissioned.

STAR FACT

Advanced Gas Reactor

The Advanced Gas Reactor or AGR was developed in the UK. The nuclear fuel used is enriched uranium oxide. The neutron moderator is graphite, and the coolant is carbon dioxide.



Control Room of Fukushima Nuclear Power Plant

South Africa

Though South Africa had nuclear weapons in the 1980s, it chose to voluntarily destroy the existing ones and stop production of future weapons. It was the first country in the world to take such a step.

Why was the Fukushima accident a great tragedy?

The reactors at the Fukushima Nuclear Power Plant were Boiling Water Reactors - BWR. A BWR produces electricity by boiling water, and spinning a turbine with that steam.

On March 11th 2011, a major disaster occurred at the Fukushima Plant, when a severe earthquake off the northwest coast of Japan triggered a tsunami.

After the earthquake, the reactors at Fukushima that were running were stopped, but to cool the reactors, electricity is needed. So, the cooling could not be carried out, and a meltdown of the reactors occurred, releasing radioactive materials into the environment.

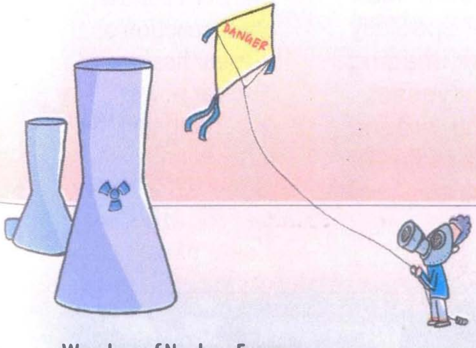
What was the Chernobyl disaster?

The Chernobyl disaster is considered the worst nuclear power plant accident in history.

On April 26th, 1986, a sudden surge of power during a reactor systems test destroyed a unit of the nuclear power station at Chernobyl, in Ukraine. The accident, and the fire that followed, released massive amounts of radioactive material into the environment.

A few weeks after the accident, the emergency crews completely covered the damaged unit in a temporary concrete structure, called the 'sarcophagus,' to limit further release of radioactive material.

More than a million people were affected. The radiation level was 100 times more powerful than the atomic bombs dropped by the US on Hiroshima and Nagasaki.



Chernobyl Nuclear Power Plant

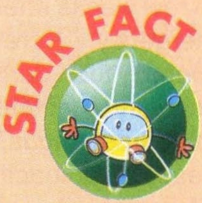
US President's visit to Three Mile Island

What were the effects of the accident at Three Mile Island?

America's worst accident at a civilian nuclear power plant occurred on March 28th, 1979, at Three Mile Island near Harrisburg. A combination of stuck valves, misread gauges, and poor decisions led to a partial meltdown of the reactor core, and the release of radio-active gases into the atmosphere.

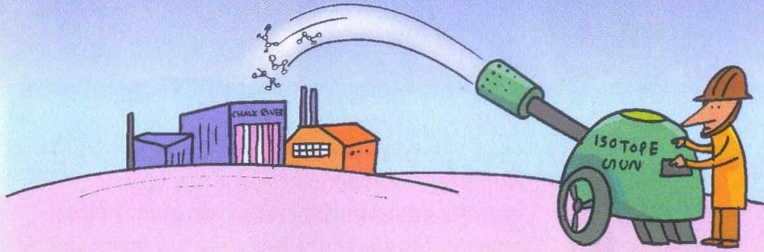
Large quantities of radioactive material leaked from the reactor, but most of it was contained. The enormous damage to the reactor was revealed only years later when TV cameras, and a specially developed ultrasonic, sonar-like imaging system looked inside the reactor vessel.

Thirty thousand people living around the nuclear plant, spread over a radius of 8 km, were exposed to certain levels of radioactivity. The accident heightened public fears, and led to the immediate shutdown of several plants.



Bombs and Reactors

In atomic bombs, there is a sudden chain reaction of nuclear fission. Nuclear power generators, on the other hand, regulate this chain reaction at a slower pace.



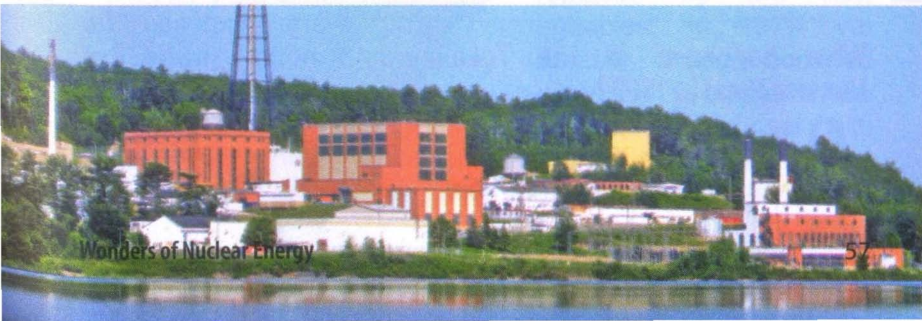
How did the nuclear accident happen at Chalk River?

Chalk River is the site of a nuclear research facility where a nuclear power reactor experienced a serious nuclear accident on December 12th, 1952.

The accident occurred when an operator of the reactor mistakenly opened four valves that served to keep air pressure from reaching the control rods. Attempts by the supervisor to prevent further damage actually compounded the problem.

Three minutes after these errors, a series of hydrogen gas explosions pitched a four-tonne dome into the air. The reactor core could not be decontaminated, but had to be buried as radioactive waste. Five years later, in 1958, several metal rods of uranium fuel were overheated, and broke inside the reactor core. One of the damaged rods caught fire, and broke in two.

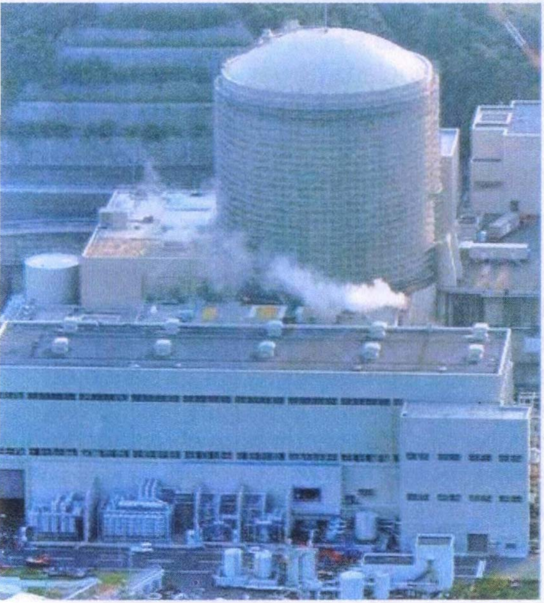
Chalk River Nuclear Power Plant



STAR FACT

Fusion Advantage

Nuclear fusion does not produce any harmful gases and therefore produces clean energy. It is also safe, because the reaction stops itself to cut the fuel supply.



Tokaimura Nuclear Plant

What happened at the Tokaimura Nuclear Plant in 1999?

On September 30th, 1999, a nuclear accident happened in a facility northeast of Tokyo. Three workers at a uranium-processing plant, in Tokaimura which was then the centre of the Japanese nuclear power industry, improperly mixed a uranium solution.

A blue flash occurred, and a worker was knocked unconscious. Within minutes, others were nauseated, and their hands and faces were burned bright crimson.

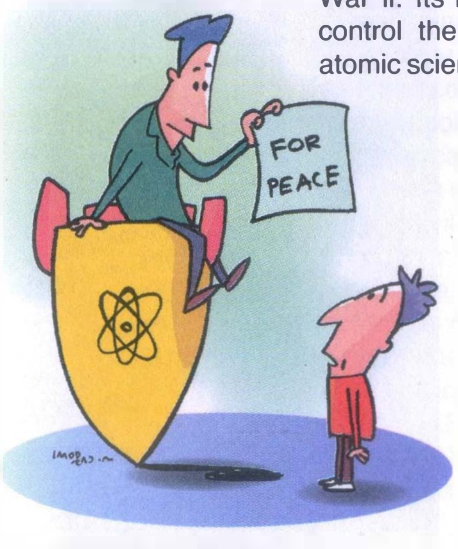
Two ended up dying, and hundreds were exposed to various levels of radiation.

Radiation levels became 15,000 times higher than normal.

US President Harry S Truman
Signs the Atomic Energy Act, 1946

Why was the Atomic Energy Commission established by the United States?

The United States Atomic Energy Commission was established after World War II. Its mission was to promote and control the peacetime development of atomic science and technology.



On August 1st 1946, the control of the AEC was transferred from military to civilian hands. However, the Commission came in for a lot of criticism, and was replaced by two new agencies. In 1977, yet another change occurred when the US created a new department to deal with atomic energy, called the Department of Energy.

What is the Nuclear Non Proliferation Treaty?

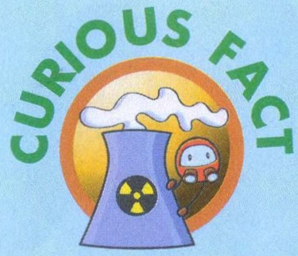
By the beginning of the 1960s, nuclear weapons technology was becoming widespread.

As a result, by 1964, there were five nuclear powers in the world- the US, the USSR, the UK, France and China.

The spread of nuclear weapons technology meant that the chances for a nuclear war also increased, and this led to the Nuclear Non Proliferation Treaty. The word 'proliferation' is a big word that simply means a rapid increase in numbers.

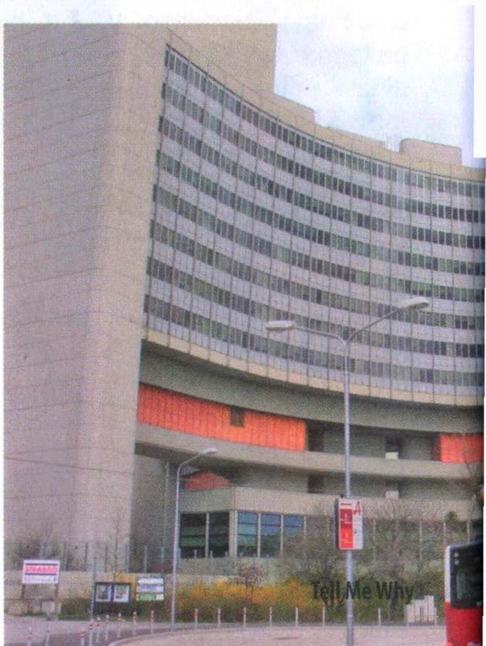
The Nuclear Non Proliferation or NPT, is an agreement signed in 1968, by of the major nuclear and non-nuclear powers that pledged their cooperation in stemming the spread of nuclear technology.

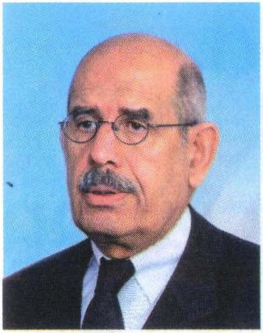
The treaty came into force in 1970, and its membership includes 188 nations. It is the largest of any arms control treaty in the world.



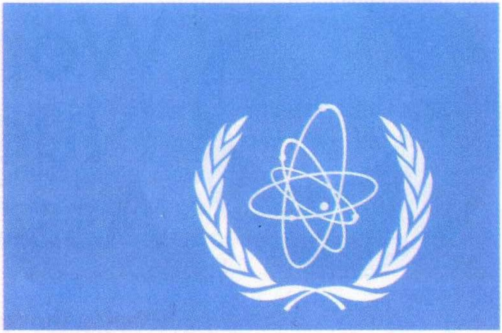
Inside the Sun

Nuclear reactions inside the sun change hydrogen into helium. About four million tonnes of mass are lost every second during this process, releasing enormous amounts of energy.





Mohamed ElBaradei



Flag of IAEA

Why is the IAEA important?

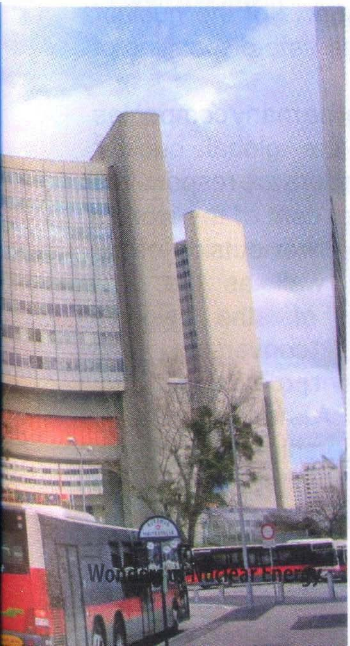
The International Atomic Energy Agency, or IAEA, has an important role to play in the nuclear world.

Its mission is to promote the peaceful use of atomic energy and prevent its use for military purposes. The agency was established by representatives of more than 80 countries in October 1956, and officially came into force on July 29th, 1957, with its headquarters in Vienna.

Its activities include research on the applications of atomic energy to medicine, agriculture, and industry, as well as the operation of conferences, and training programme to promote the exchange of technical information and skills.

The IAEA and its Director General, Mohamed ElBaradei won the Nobel Prize for Peace in 2005.

Head Quarters of IAEA



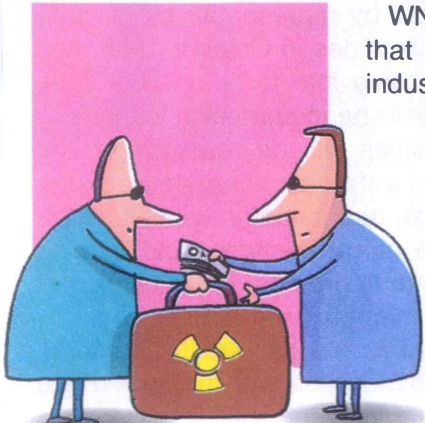
World Nuclear Association

What is the role of the World Nuclear Association?

The World Nuclear Association or WNA is the global organization that seeks to promote the peaceful use of nuclear power worldwide.

Established in 2001, the WNA is concerned with nuclear power generation and all aspects of the nuclear fuel cycle and the safe disposition of used fuel.

WNA supports the many companies that comprise the global nuclear industry. Its members are responsible for 95 per cent of the world's nuclear power outside of the U.S. as well as the vast majority of the world's uranium, conversion and enrichment production.



The WNA is funded primarily by membership subscriptions, and is accredited to the United Nations.

Fossil Fuel

Ninety per cent of the world's electricity needs are met by the burning of fossil fuels that emit dangerous gases. These gases cause global warming. Nuclear power is a clean alternative that many countries are opting for today.

The Symbol of International Radioactive Waste Hazard.

What is nuclear waste?

Nuclear wastes are radioactive wastes that are the by-products of nuclear power generation.

Radioactive wastes can be high level, middle level, and low level. Radioactive waste is produced by a number of sources, but by far the largest quantities are generated by the nuclear power plants, and nuclear weapons production industries.

One of the major problems associated with radioactive waste is the fact that it will require isolation from the human environment – for hundreds of years.

Removal of Low Level Waste

A Low Level Waste Storage Pit.

How is nuclear waste classified?

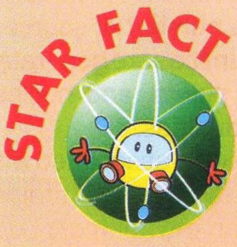
In general, radioactive waste is classified based on the waste's origin, not on the physical and chemical properties of the waste.

High-level waste from a nuclear reactor is the used nuclear fuel left after it has spent years in the reactor. It is also known as spent fuel.

Middle level wastes include fuel cladding and wastes from fuel reprocessing. Low-level waste is made up of lightly-contaminated items like tools and work clothing from power plants.

Each level of waste has to be disposed of in a different manner to ensure that safety standards are met.

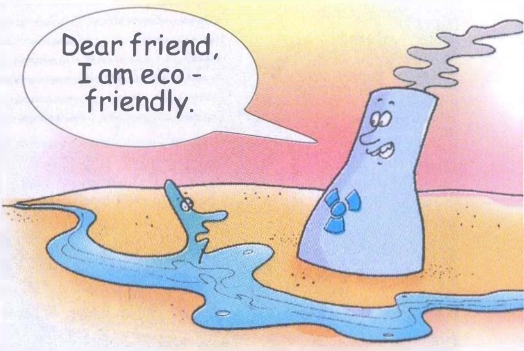
Spent fuel is stored in pools of water near the reactor until a permanent location is prepared. Middle level wastes may be solidified in concrete or bitumen, and then buried. Low-level waste can often be compacted or incinerated in a container, that is subsequently, buried a landfill.



GCR

GCR or gas cooled reactors use carbon dioxide as the coolant to carry the heat to the turbine, and graphite as the moderator.

How does nuclear energy affect the environment?



Nuclear energy is 'clean energy' in the sense that it does not cause air pollution.

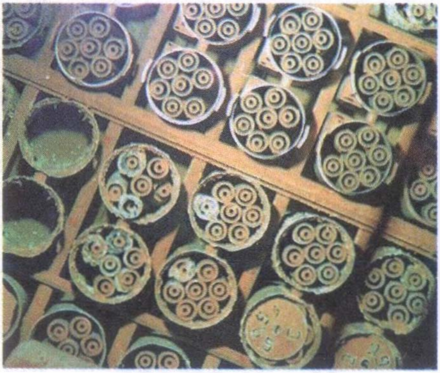
However, the mining, enrichment, and transportation of uranium for nuclear energy cause some degree of harm to the environment.

Nuclear power plants use large quantities of water for steam production and cooling, for which large quantities of water from a lake or river are required. This could affect fish, and other aquatic life.

The waste material produced by nuclear plants is dangerously radioactive, and should never be allowed to escape into the environment.

However, accidents do occur, with disastrous results. Workers in nuclear plants wear special badges called dosimeters which record whether they have been exposed to any radiation, and if so, how much.

Finally, the setting up of a nuclear plant requires a large area, preferably situated near a natural water body. This is usually accompanied by the clearing of forests, which disturbs the habitats of many creatures, and gradually upsets the natural balance of the region.



Spent Fuel Stored Under Water

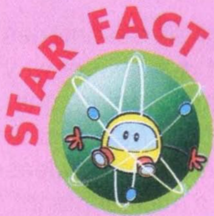
Nuclear Flasks in Transit

What is a nuclear flask?

A nuclear flask is a container that is used to transport active nuclear materials by ship or train. Nuclear fuel has to be taken from where it is processed, to the reactors where it is used.Fuel that has reached the end of its useful life must be transported from power plants for reprocessing and storage. In both cases, the fuel must not be allowed to leak or escape while it is being moved, even if the container transporting it is involved in a serious accident.

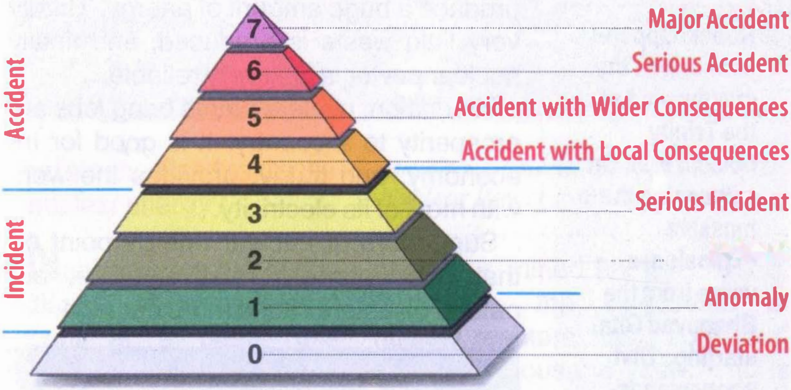
Nuclear flasks are designed to seal the radiation inside and withstand any accident, including a deliberate attack by terrorists, being dropped from a height, or surviving a fierce fire for more than half an hour.

Each flask is made of steel, and weighs between 50 and 110 tonnes.



Gas Cooled Reactor

High temperature gas cooled reactors use a gas as the primary coolant. These reactors can achieve significantly higher efficiencies than PWRs, but the power output is limited by the less efficient cooling power of the gas.



What is INES?

INES stands for the International Nuclear and Radiological Event Scale.

This scale is similar to the one that measures the magnitude of earthquakes. Each level of the scale represents an accident that is 10 times more serious than the previous level. The scale starts from Level 0, and has seven levels altogether, three at the incident level, and four at the accident level.

INES was introduced in 1990 by the International Atomic Energy Agency. It is a tool for promptly communicating to the public, the significance in terms of safety, of reported nuclear and radiological incidents and accidents.

STAR FACT

Gita and Trinity

Robert Oppenheimer was the mastermind of the Trinity nuclear test. On witnessing the massive explosion, a verse from the Bhagavad Gita, starting, 'Divi sooryasahasrasya....,' flashed through his mind. The verse means, 'if the radiance of a thousand suns were to burst at once into the sky, that would be similar to the the splendour of that mighty one.'

What are the advantages of nuclear energy?

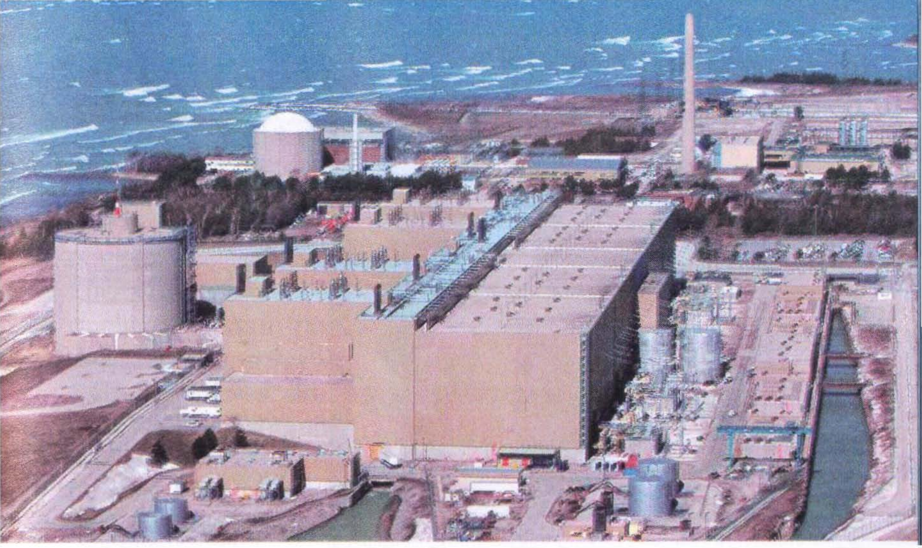
To begin with, one of the advantages of nuclear energy is that it is a cleaner way to produce electricity than burning gas or fossil fuels like coal. No smoke, carbon dioxide, or other pollutants are released into the atmosphere by a nuclear plant.

Secondly, a small amount of fuel can produce a huge amount of energy. Thirdly, very little waste is produced, and finally, nuclear power is also very reliable.

In addition, nuclear plants bring jobs and prosperity to a country. It is good for the economy, and today, provides the world with most of its electricity.

Supporters of nuclear energy point out that accidents are relatively rare, and natural disasters cause more damage.

A Nuclear Power Station in Germany



Bruce Nuclear Station- The Largest Nuclear Power Facility in the World

What are the disadvantages of nuclear energy?

Nuclear energy produces radiation. If an accident occurs at a plant, this radiation is released.

It consists of subatomic particles that penetrate deep inside the human body, and initiate cancer. It can affect future generations too. In many cases, survivors of a nuclear blast give birth to tragically deformed children.

Uranium, the main fuel in nuclear plants, is not renewable, and can lead to environmental problems when it is mined and processed. Plutonium, the by-product of nuclear reactors, has a half-life of about 10 thousand years, and is therefore, hard to dispose of.

Nuclear waste is radioactive and highly dangerous. Nuclear waste must be safely sealed and buried underground for thousands of years to allow the radioactivity to die away.

During this time, it must be kept safe from earthquakes, floods, and terrorists.

Finally, nuclear power plants are very expensive to build, and have a life of only around 40 years.

Equipment used for diagnostic test in Nuclear Medicine

What are the other applications of nuclear energy?

Nuclear energy is used mainly to produce electricity, but it has many other uses as well.

In industry, it plays an important role in improving processes for measurement, automation, and quality control.

In medicine, nuclear energy is used for diagnosis and vaccine preparation, as well as the treatment of diseases.

In the field of food processing, nuclear energy can help in the conservation of food, while the environmental uses of nuclear energy include tackling problems like the greenhouse effect, water pollution, control of insects and other pests.

Other uses of nuclear energy include 'dating' or determining the age of fossils, as well as for powering submarines.

STAR FACT

Radiation and Health

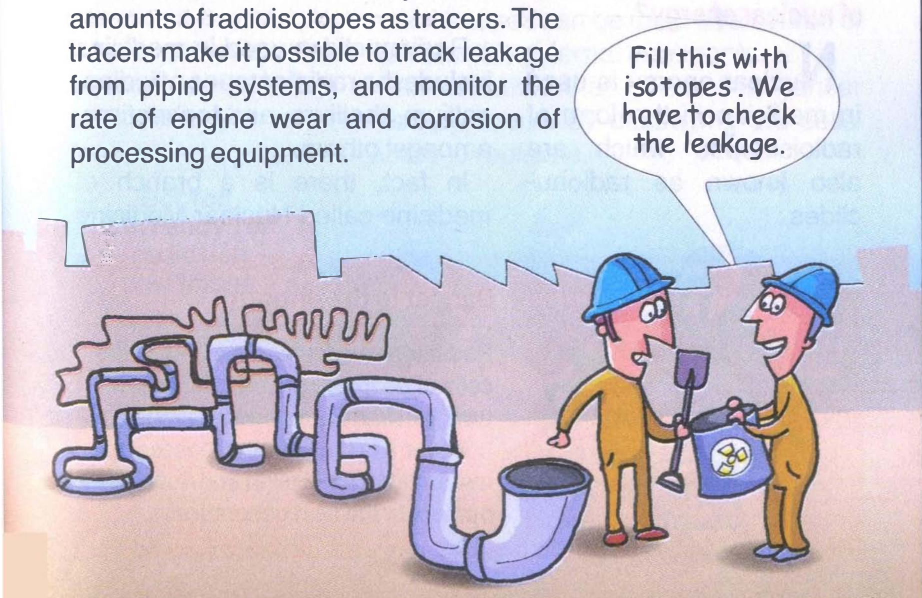
High doses of radiation can cause ulcers, burns on the skin, and damage to the bone marrow, and in the long term, can lead to cancer.

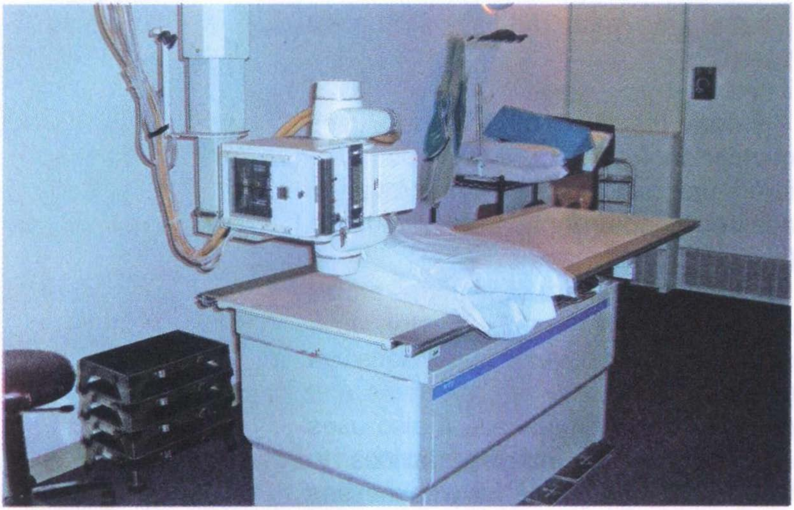
What are the industrial uses of nuclear energy?

Today, practically every industry uses nuclear energy in some way. Manufacturers use radioisotopes to improve the quality of goods in thousands of industrial facilities around the world.

Radioisotopes, are radioactive atoms of ordinary elements. Industry uses radioisotopes to develop highly sensitive gauges to measure the thickness and density of many materials. It also uses radioisotopes as imaging devices to inspect finished goods for weaknesses and flaws.

Manufacturers commonly use small amounts of radioisotopes as tracers. The tracers make it possible to track leakage from piping systems, and monitor the rate of engine wear and corrosion of processing equipment.





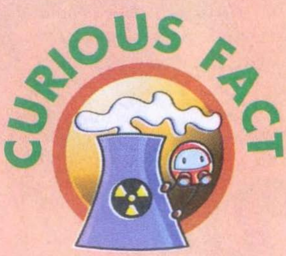
A Radiology Room

What are the medical uses of nuclear energy?

Nuclear energy is used in medicine in the form of radioisotopes which are also known as radionuclides.

Radionuclides used in medicine include the radioisotopes of iodine, gallium, thallium, and technetium, amongst others.

In fact, there is a branch of medicine called Nuclear Medicine



Danger to the Unborn

Radiation can damage the DNA in the cells of people exposed to it. This, in turn, can harm future generations, because it is the DNA that passes on instructions for growth and development to the next generation.

that uses radiation to provide information about the functioning of a person's specific organs, or to treat disease.

In most cases, the information is used by physicians to make a quick, accurate diagnosis of the patient's illness.

The use of X-rays for examining patients is called diagnostic radiology, and when radiation beams are used to treat patients, the procedure is called radiotherapy.

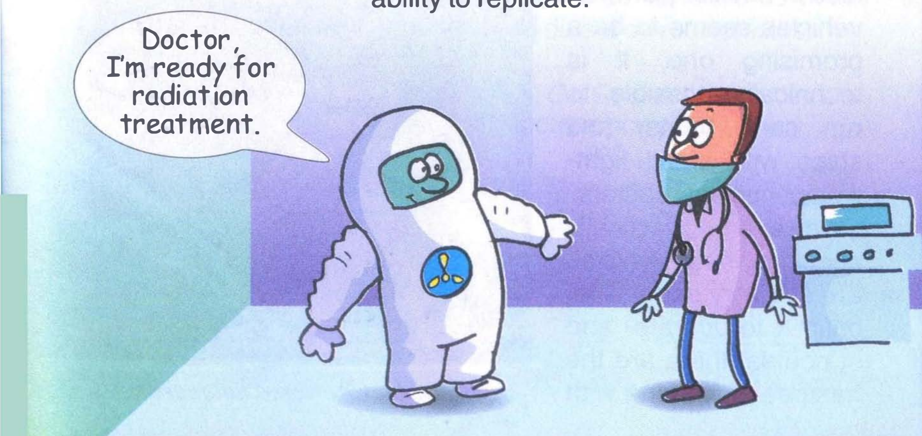
How is nuclear energy used to battle cancer?

One way in which radioisotopes battle cancer is by helping to detect it.

In a 'bone scan,' a tracer is injected into the blood and, a short while later; the whole body is scanned with x-ray detectors. Areas of bone with heightened biological activity, such as a cancer site, will absorb more of this tracer, and register a higher rate.

Radiotherapy can be used to weaken, or destroy particular targeted cells. In one application, radioisotopes are implanted in the body at the cancer site in little pellets called seeds. Alternatively, radioisotopes can be used as a source of radiation for external treatments.

All radiation that is used in cancer therapy, works by destroying the cells' ability to replicate.



What is the relationship between nuclear energy and global warming?

Carbon dioxide is widely believed to be one of the main causes of global warming.

Carbon dioxide is a greenhouse gas that is emitted by human activity, including the use of fossil fuels like coal.

Alternative sources of energy like wind and solar energy cannot meet the worldwide growing demand for power.

Today, nuclear energy is the only large-scale, cost-effective energy

What are nuclear powered vehicles?

With the discovery of nuclear energy, the idea of nuclear powered vehicles seems to be a promising one. It is technically possible to run cars, trains, and ships with small light-weight nuclear reactors.

However, practically speaking, such vehicles are still very expensive, difficult to operate- and of course, there are the hazards of working with radioactive materials too. For this reason, at present the majority of nuclear powered vehicles are submarines.

A Nuclear Powered Submarine

source that can reduce carbon dioxide emissions, while continuing to satisfy the increasing energy needs of our planet.

Nuclear methods such as electron beam irradiation are also very useful for removing gaseous pollutants, including harmful gases like sulfur dioxide or nitrogen oxide, from the atmosphere.

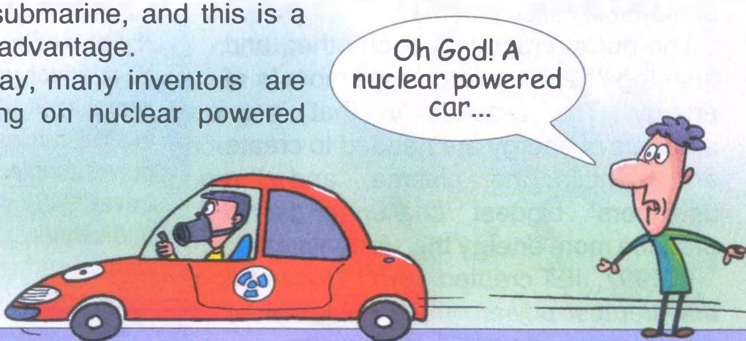
STAR FACT

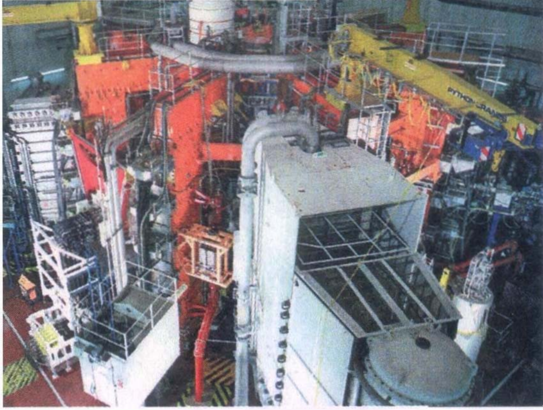
Tokamaks

Fusion reactors, which have a doughnut- shaped magnetic chamber, are called tokamak reactors. The word 'tokamak' is derived from a Russian word meaning doughnut- shaped.

In the case of submarines, nuclear power enables them to stay submerged for long periods without surfacing to refuel. Since nuclear engines do not 'burn' fuel, they do not use up precious oxygen supply in a submarine, and this is a great advantage.

Today, many inventors are working on nuclear powered cars and trains too, and perhaps, one day, they will become as common as petrol and diesel driven vehicles.





Joint European Torus-World's Largest Fusion Reactor

What is JET?

JET stands for Joint European Torus. It is the world's largest fusion reactor. It cost 500 million dollars to build, and was paid for by the countries of the European Union.

Initially designed in the 1970s, this reactor is located in Culham in the United Kingdom.The fuel is heated to an incredibly high temperature at which electrons are stripped away from atoms, leaving just nuclei. This super-hot state of matter is called plasma.

The nuclei crash into each other, and fuse together to create vast amounts of energy. The problem is that huge amounts of energy are needed to create and contain the plasma, and the designers' biggest challenge is to produce more energy than is consumed.

In 1997, JET created a world record of the greatest power output achieved by any fusion reactor- 16.1 megawatts.

First Nuclear Submarine

The world's first nuclear powered submarine was the Nautilus of the US Navy, which was launched in 1954. In 1958, nuclear power enabled it to travel 2945 km underwater, without surfacing.

● *Sneha Rao*

Nuclear Weapons

What are nuclear weapons?

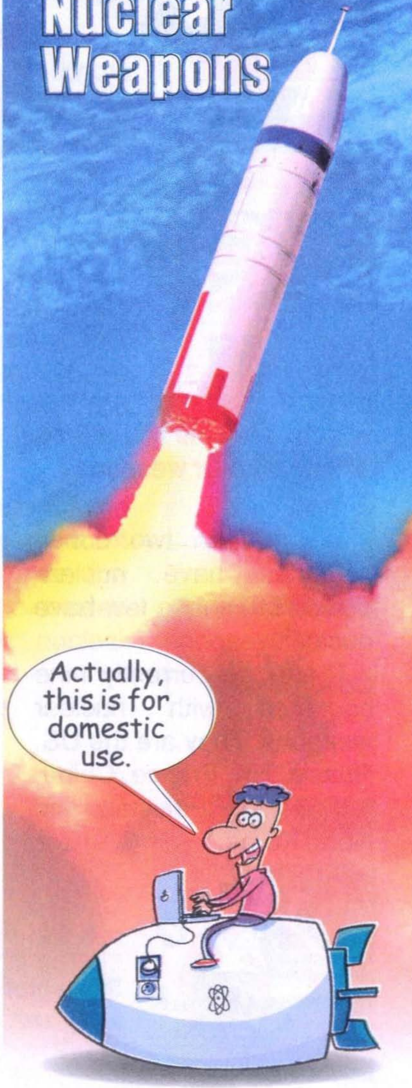
Nuclear weapons are weapons that release energy in an explosion that is caused by nuclear fission, nuclear fusion, or a combination of the two processes.

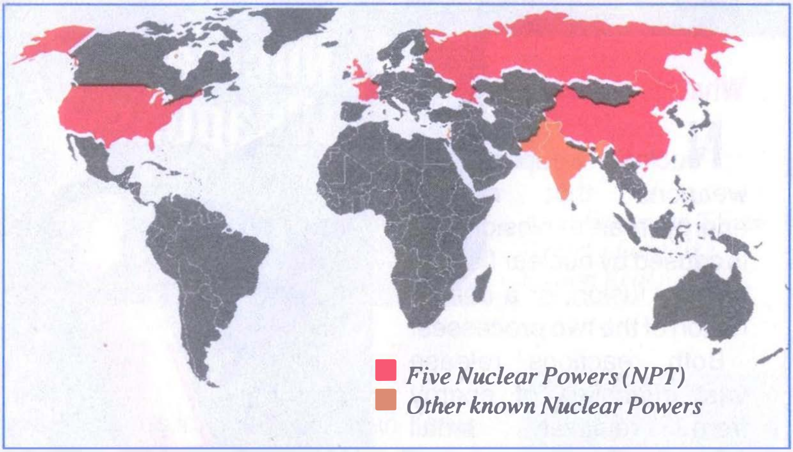
Both reactions release vast quantities of energy from relatively small amounts of matter.

Even a small nuclear device, no larger than traditional bombs, can devastate an entire city by blast, fire, and radiation.

So far, nuclear weapons have been used only twice, at the end of World War II when the US dropped two bombs on Japan, completely wiping out the cities of Hiroshima and Nagasaki, and forcing the Japanese to surrender.

Nuclear weapons are weapons of mass destruction, and there are enough of them to destroy civilization, and most life on Earth.





Which are the countries having nuclear weapons?

More than two dozen countries have nuclear power, but only a few have nuclear weapons.

There are currently nine countries with nuclear weapons. They are the US, Russia, UK, France, China, Israel, India, Pakistan, and North Korea.

Each of the nine countries with nuclear weapons guards their exact number as a closely held national secret, but more than 95 percent of all nuclear weapons are believed to be in the arsenals of the US and Russia. Nations that are believed to possess nuclear weapons are sometimes referred to as the nuclear club. The US was the first country to develop nuclear weapons, and the only country to have used them in war.

Nuclear Powered Spacecraft

Space probes sent out to study the solar system and planets are powered by nuclear energy.

● *Dev Nath*

How many nuclear weapons are there in the world?

It is difficult to give an exact figure for the number of nuclear weapons in the world.

In 2013, it was estimated that there were approximately 17,300 nuclear warheads in the world. Nuclear warheads are the warheads of weapons designed to deliver a nuclear bomb. Out of this number, Russia is believed to have 8500 and the USA has 7700. Of the other countries France has 300, China has 250, and the UK has 225. In addition, Pakistan and India have 100 respectively, while Israel has 80, and North Korea has around 10.

The availability of reliable information about the nuclear weapons in different countries varies considerably. France, the UK and the USA have recently disclosed important information about their nuclear capabilities.

B 53 Nuclear Bomb on Display

What are fission weapons?

Fission is the splitting of an atom. Not all atoms will go through fission- as a matter of fact, very few do, under normal circumstances.

Fission weapons are weapons that have explosive power which results from the sudden release of energy upon the splitting or fission, of the nuclei of such heavy elements as plutonium or uranium. They are normally made with materials having high concentrations of the fissile isotopes uranium-235, plutonium-239, or some combination of these.

In a fission weapon, a series of rapidly multiplying fissions culminates in a chain reaction, in which nearly all the fissionable material is consumed. This results in the explosion of what is known as an atomic bomb.

STAR FACT

The First Hydrogen Bomb

The first scientists to discover the fact that energy is created when nuclei are fused together were Atkinson and Houtermans. They discovered this in 1929. The US detonated the world's first thermonuclear weapon, the hydrogen bomb, in 1952.

Operation Castle- A Thermonuclear Test

How are fusion weapons different from fission weapons?

Nuclear fusion is the process by which more than one nuclei join together to form a heavier nucleus. Nuclear fission is the exact opposite process, in which the nucleus of an atom splits into two or more smaller nuclei.

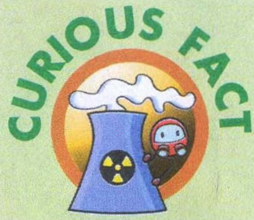
Nuclear weapons use both fusion and fission. Fission bombs are known as atom bombs. In fission weapons, enriched uranium or plutonium is assembled into what's called a super-critical mass, which starts a rapidly growing nuclear chain reaction, resulting in an explosion.

Fusion bombs work by detonating a fission bomb adjacent to a fusion fuel, which starts a fusion reaction. Fusion bombs are more destructive than fission bombs.

Why is the neutron bomb the most destructive?

A neutron bomb uses fusion to increase the production of radiation beyond that which is normal for an atomic device. In a neutron bomb, the burst of neutrons generated by the fusion reaction is purposely not absorbed inside the weapon as in other bombs.

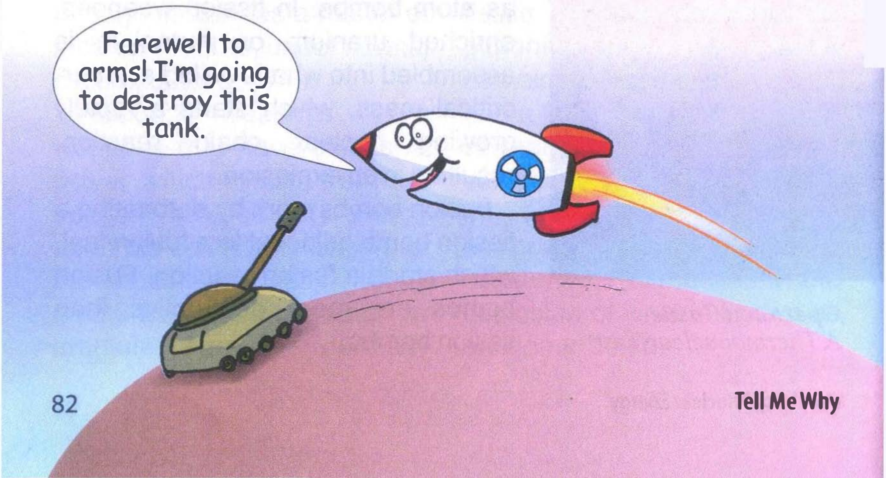
Instead, it is allowed to escape, and the intense burst of high-energy neutrons is tremendously destructive, because neutrons are more penetrating than other types of radiation. As a result, the usual shielding materials are not effective against neutron bombs. By emitting large amounts of lethal radiation of the most penetrating kind, these bombs maximize the lethal range of nuclear weapons against armoured targets.



Other Bombs

There are also other types of nuclear weapons. These include fission bombs that enhance their explosive yield through a small amount of fusion reactions, but are not actually fusion bombs.

● *Radha Nair*



Nuclear India

Agni II of Indian Army in the Republic Day Parade

Why is nuclear power important in India?

India's hunger for electricity is enormous, anditsenergyconsumption doubled between 1990 and 2011.

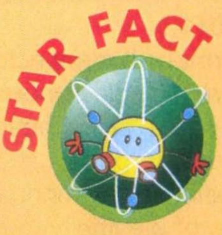
Thermal, hydroelectric, and renewable sources meet some of its needs, but nuclear power is an increasingly important source of electricity in the country.

In 2012, India had 21 nuclear reactors in

operation in six nuclear power plants, with seven other reactors under construction. Nuclear power in India is poised to undergo a significant expansion in the coming years, in part due to the passing of the US -India Civil Nuclear Agreement.

This agreement will allow India to carry out trade of nuclear fuel and technologies with other countries. Consequently, there will be a significant increase in its power generation capacity to satisfy the power needs of a rapidly expanding economy. India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

Prithvi Missile



BARC

Bhabha Atomic Research Centre (BARC) is India's premier nuclear research institute based in Trombay, Mumbai. It is named after India's renowned nuclear scientist Dr. Homi J. Bhabha. BARC conducts researches to sustain peaceful applications of nuclear energy mainly for power generation. Besides that BARC operates a number of research reactors across the country.

What is the history of Nuclear India?

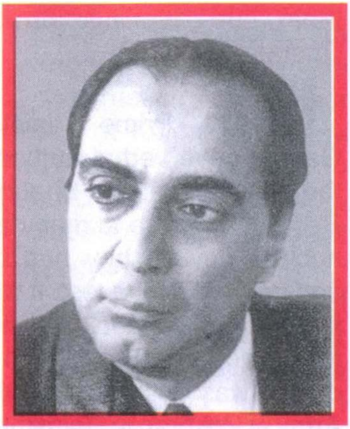
India entered the Nuclear Age in 1948, when the Atomic Energy Commission was established with Dr. Homi Bhabha as the Chairman.

India's first research nuclear reactor, and its first nuclear power plant were built with assistance from Canada. By 1963, India had two research reactors and four nuclear power reactors.

The next milestone was on May 18th, 1974 when India conducted a peaceful nuclear explosion. More nuclear power reactors were built, without any foreign collaboration, and on May 11th and 13th 1998, India successfully exploded both fission and fusion devices.

In order to meet its nuclear energy requirements, India has signed agreements with a host of countries to obtain uranium for its nuclear power plants.

The future of nuclear cooperation for India with various countries is bright, as India tries hard to increase its nuclear power output.



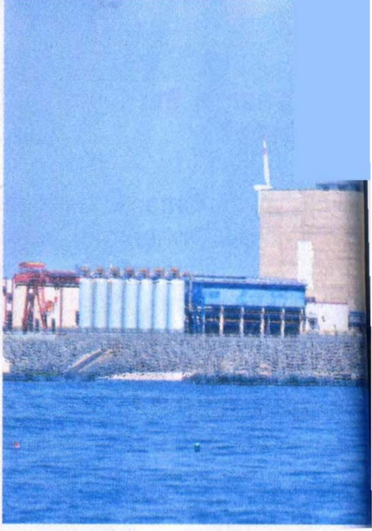
Dr. Homi Bhabha

Former Prime Minister Indira Gandhi at the Test Site in Pokhran

What are Smiling Buddha and Operation Shakti?

In 1972, Prime Minister Indira Gandhi gave verbal authorisation to the scientists at the Bhabha Atomic Research Centre to manufacture the nuclear device they had designed, and prepare it for a test. It was India's first nuclear weapon explosion, which took place on 18th May, 1974. The device was detonated by the Indian Army at Pokhran in Rajasthan.

On May 11th 1998, Operation Shakti was launched, when India carried out three underground nuclear tests at the Pokhran Range. The first blast had a yield of 12 kilotonnes, the second was a thermonuclear device with a yield of 43 kilotonnes, and the third was a low yield device. All three devices were detonated simultaneously. On May 13th, India conducted two further tests, on low yield devices.



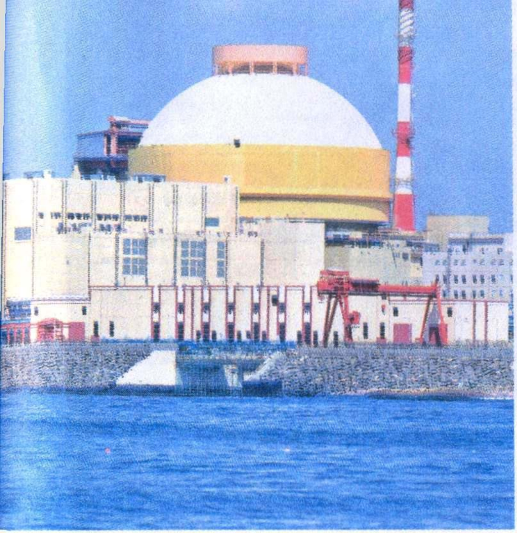
Kudankulam Reactor

What do we know about India's fast breeder reactors?

A breeder reactor is a nuclear reactor capable of generating more fissile material than it consumes, and a fast

Agni V

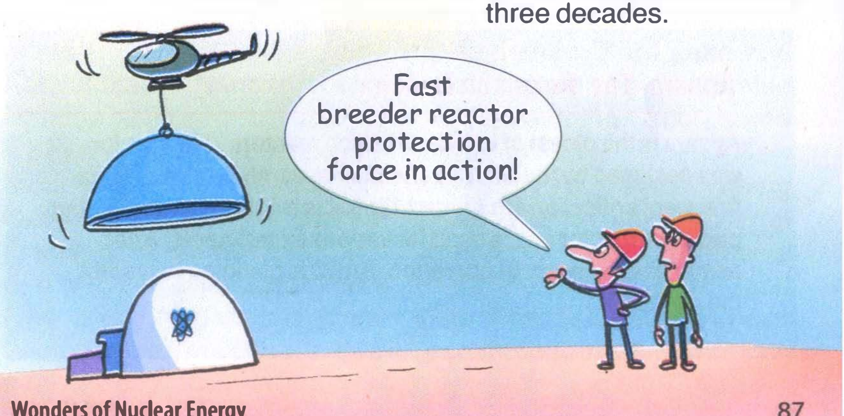
Agni V is India's long range ballistic missile which can carry a nuclear warhead as far as China in the east, and Europe in the west. It has a range of 5,000 kilometres, giving it the farthest reach among all Indian missiles.



breeder reactor is one in which the neutrons are not slowed down by a moderator.

India's first fast breeder reactor went into operation in 1985. At present, the scientists of the Indira Gandhi Centre for Atomic Research, which is one of the nuclear research institutions of India, are engaged in the construction of another one at Kalpakkam, near Chennai, with plans to build more as part of its three stage nuclear power programme.

India's first commercial scale fast breeder nuclear reactor is set to be commissioned in September 2014. The 500MW Prototype fast breeder reactor or PFBR- located at Kalpakkam in Tamil Nadu- is intended to be a forerunner of a series of home-grown reactors that are expected to dramatically boost India's nuclear power generation capacity over the next three decades.



Tarapur Atomic Power Station

Where do we find uranium deposits in India?

From a modest beginning in 1948, the atomic energy programme of India has grown to vast dimensions. The uranium ore mining and processing industry of the country began at Jaduguda in 1968.

Jaduguda was the first uranium deposit to be discovered in the country in 1951. This discovery paved the way for intensive exploration work, and soon, a few more deposits were brought to light. Some of these deposits like Bhatin, Narwapahar and Turamdih are well known uranium mines of the country today. Other deposits like those at Bagjata, Banduhurang and Mohuldih are being taken up for commercial mining. In addition, there are limited reserves in

Apsara -The Research Reactor

Apsara is the oldest of India's research reactors . The reactor was designed by the Bhabha Atomic Research Centre. Apsara first went critical on 4th August 1956. It is a light water swimming pool type reactor and is used for various experiments. After nearly half a century of operation, BARC is planning to modify the reactor.

India's operating nuclear power reactors:

Reactor	State	Type
Tarapur1 & 2	Maharashtra	BWR
Kaiga 1 & 2	Kamataka	PHWR
Kaiga 3 & 4	Karnataka	PHWR
Kakrapar 1 & 2	Gujarat	PHWR
Kalpakkam 1 & 2	Tamil Nadu	PHWR
Narora 1 & 2	Uttar Pradesh	PHWR
Rajasthan 1	Rajasthan	PHWR
Rajasthan 2	Rajasthan	PHWR
Rajasthan 3 & 4	Rajasthan	PHWR
Rajasthan 5 & 6	Rajasthan	PHWR
Tarapur 3 & 4	Maharashtra	PHWR
Kudankulam 1	Tamil Nadu	PWR

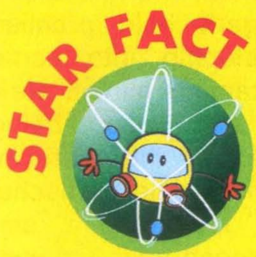
areas like Garadih, Kanyaluka, Nimdih and Nandup.

Several uranium deposits have also been found in Cuddapah basin of Andhra Pradesh. In the northeastern part of the country, sandstone type uranium deposits have been discovered. Other areas in Rajasthan, Karnataka and Chattishgarh hold promise for developing into some major uranium mines. New mines are also being developed in the state of Jharkhand, while Himachal Pradesh, Maharashtra, and Uttar Pradesh have uranium resources too.

Why does India focus on thorium enrichment?

Thorium is a naturally-occurring, slightly radioactive metal found in small amounts in most rocks and soils, where it is about three times more abundant than uranium. It exists in nature in a single isotopic form, Th-232, which decays very slowly - its half-life is about three times the age of the Earth. India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium, which be used as a fuel in conjunction with a fissile material such as recycled plutonium. There are seven types of reactors into which thorium can be introduced as a nuclear fuel.

India has one of the largest deposits of thorium in the world. There are about 10.70 million



Most Powerful Nuclear Device

The USA detonated a nuclear device at the Bikini Atoll of the Marshall Islands on March 1st, 1954. It was named 'Castle Bravo,' and was about 1,000 times more powerful than each of the atomic bombs which were dropped on Hiroshima and Nagasaki during World War II.

INS Arihant

tonnes of monazite in the country, which contains 9,63,000 tonnes of thorium oxide. India is pursuing a three-stage nuclear power generation programme aimed at long term energy independence, based on the use of our abundant thorium resources. Today, India is ready to build a large-scale prototype of a reactor fueled by a combination of thorium and low-enriched uranium.

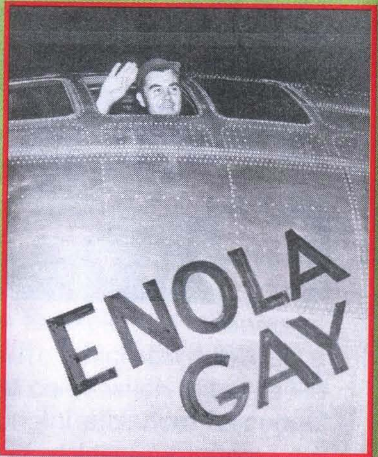
Why is INS Arihant India's pride?

The nuclear submarine INS Arihant is the pride of the Indian Navy. It is the first nuclear submarine to be designed and built in India. It is also the first ballistic missile submarine known to have been built outside the five big nuclear powers. India had previously operated a Soviet nuclear submarine until 1991. INS Arihant has been fitted with a mobile nuclear reactor, which powers the submarine.

Nuclear submarines will add a third dimension to India's defense capability, as it has previously only been able to launch ballistic missiles from the air, and from land. When it is eventually deployed, the Arihant will be able to carry a crew of about 100 sailors on board.

Photo Zone

The poster released by the US before the attack on Japan, during World War II.



Paul Tibbets, the pilot of Enola Gay, just before flying to Hiroshima for bombing.

Enola Gay -B 29, Super fortress bomber, the first aircraft to drop an atom bomb.

The crew of Enola Gay.

Paul Tibbets

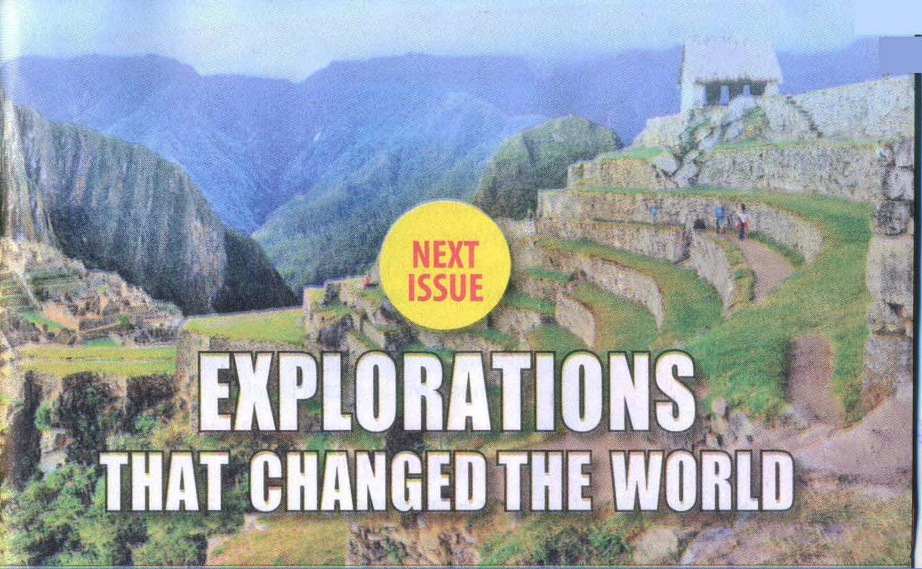
The crew of Bockscar, the aircraft that bombed Nagasaki.

USS Nautilus - World's first nuclear powered submarine.

Hiroshima Peace Memorial Museum, Japan - dedicated to documenting the atomic bombing.

Atomic Bomb Dome, Hiroshima, Japan - Memorial to the people killed in the atomic bombing of Hiroshima.

The watch recovered from Hiroshima, after the bombing. The hands of the watch frozen at 8.16.



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Winners of the GK Contest - 9, Flags - held in the February issue of Tell Me Why.

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2. Jinoy Varghese
Parayil House, Mathra PO, Punalur.

3. Vajra Manasa Palguna V.
Veeru G, 1412, Papanna Building,
Prashanth Nagar, T. Dasarahalli,
Bangalore, Karnataka.

4. Vaishnav Srivastava
Class-IIIB, Hill Top School,
Telco Colony, Jamshedpur.

5. Aakanksha Lolusare
Flat nos 370,
Dwarka Sector 13, Pocket A,
Rosewood Appartement,
New Delhi.

GK Contest - 9 Flags - ANSWERS

1. Australia 2. United Kingdom 3. United States of America
4. Nepal 5. Canada 6. Sri Lanka

GK CONTEST - 11

PRIME MINISTERS

Here's a contest for our readers. Identify the PERSONS, from the photos given here.

All you need to do is send us an email naming each person with the proper number.

(PLEASE GIVE YOUR POSTAL ADDRESS ALSO IN THE E-MAIL) You are also welcome to send your answers by post.

Five winners will be awarded prizes. In case there are more than five correct entries, the winners will be chosen by lot.

Last Date to receive entries:

2014 APRIL 25th

Our e-mail address:

childrensdivision@mmp.in

Please enter

TMW - GK CONTEST - 11

in the subject line of your email.

SCIENCE KIT

FOR FIVE LUCKY WINNERS

If you are sending your entry by post, superscribe this on your envelope.

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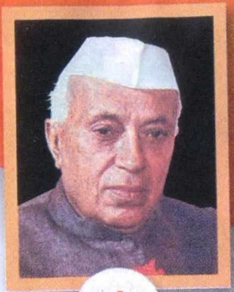

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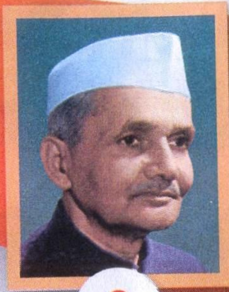

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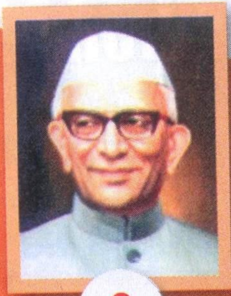

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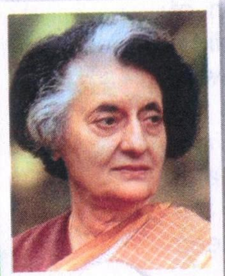

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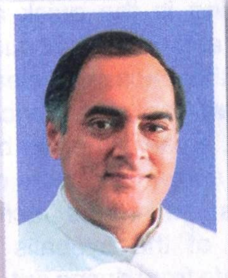

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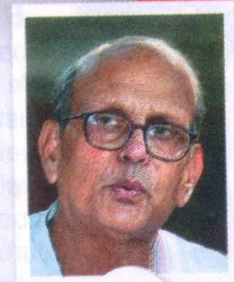

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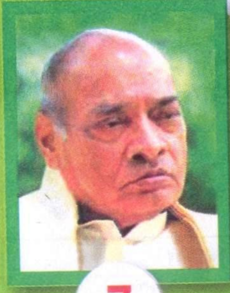

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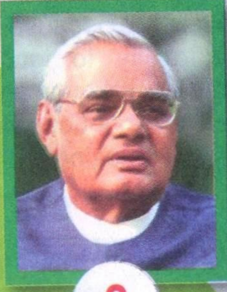

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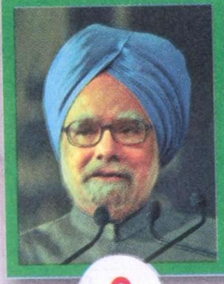

9

I Wonder Why?

Send us your questions
E mail: **tellmewhy@mmp.in**

Question of the Month

Why do we blink our eyes?

Blinking is the quick action of closing and opening of our eyelids. We do this because it clears away dust particles and lubricates the eyeball. Every time we blink, our eyelids spread a mixture of oil and mucous secretions across the surface of the eyeballs to keep them safe from drying out.

We blink approximately once in every ten seconds. But still we never experience a 'blackout'. Do you know why? Because our brain has the ability to ignore such momentary blackouts and allows us to have a continuous view of the world. Isn't it amazing?

● *Indhu Thomas*

MANORAMA TELL ME WHY - WONDERS OF NUCLEAR ENERGY

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